Moving people for tigers:

Resettlement, Food Security and Landscape-Level Conservation in Central India

Amrita Neelakantan

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ABSTRACT

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Resettlement of humans from protected areas conserves habitats for wildlife. However, impacts of resettlement on the well-being of resettled communities and on broader conservation goals at the landscape level have been poorly quantified until now due to inadequate documentation and baseline information. Recent documentation and advances in measurements of human well-being enable studies that examine the impacts of resettlement for both people and conservation.

In India, the current standardized resettlement policy by the National Tiger Conservation Authority (NTCA) is explicit in its goal to create inviolate habitats for tigers within protected areas. More than 70% of the global tiger population lives in protected areas in India. The central Indian national parks hold approximately 40% of Indian tiger populations. Implementation of the NTCA policy provides an opportunity to study resettlement with relatively accurate records of where resettled households moved, a standardized monetary compensation and the potential for replication with large representative groups to study impacts in various landscapes across the country.

This dissertation focuses on resettlement in Kanha National Park in central India, one of the most well-known and oldest tiger reserves in the country. The Kanha National Park (KNP) landscape mirrors the realities of many people-park interactions in human-dominated areas with high percentages of indigenous human populations, historical forced displacements, and current

resettlements that follow a standardized national policy. From a conservation point of view, connectivity between KNP and other protected areas across central India is crucial for genetically healthy tiger populations.

This dissertation consists of three analyses that combine data from field surveys and existing data sources to examine the impacts of resettlement on food security, landscape connectivity for wildlife, and human-wildlife conflict in the KNP landscape. In Chapter 1, I use household surveys to compare the food security and livelihood associations of resettled households compared to their non-resettled neighbors at new settlement locations. I show that resettled households have similar availability and access to foods as their non-resettled neighbors. Increases in off-farm income sources are associated with higher food access for all households. In Chapter 2, I explore the pattern of low food access in the KNP landscape using the five capitals model for sustainable development to illustrate significant associations between livelihood factors and household food access. Salaried stable incomes and kitchen garden diversity are significantly associated with higher food access. Financial capital dwarfs the contributions of social and natural capitals which have supplementary roles in times of financial stress.

In Chapter 3, I address resettlement impacts on habitat connectivity between protected areas and human-wildlife conflict that resettled households face after relocating outside the park. Resettled households are not disproportionately moving into corridors between protected areas, especially when compared to the manifold more non-resettled households already residing in these areas. Resettled households however are moving into areas of high human-wildlife conflict due to their continued proximity to KNP. Outcomes from Chapter 3 also confirm that steady incomes can alleviate forest use and lower human activities in forests reducing human-wildlife

conflict. In human-dominated landscapes such as KNP, financial capital and the stability of household incomes can aid both food security, lower pressures on non-protected forests and potentially lower human-wildlife conflict. The results counter assumptions that resettled communities continue to follow traditional natural resource reliant livelihoods. Local populations are not likely to engage in livelihoods that are heavily reliant on natural resources as rural populations become integrated into urban economies.

The results from this dissertation imply that managers in the KNP landscape can alleviate food security and aid landscape wide conservation goals by increasing off-farm salaried incomes. Finally, in India, there is a high potential for replication of this study around other protected areas, with nationally standardized resettlement in landscapes that vary geographically, ecologically and socially.

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CHAPTER 1 - INTRODUCTION

The protected area network, which now covers more than 12% of the planet's ice-free terrestrial surface, is the cornerstone of conservation (Brooks et al., 2004). Much of protected area establishment historically displaced millions of people to create habitats for wildlife (West, Igoe, & Brockington, 2006). For example, historical evictions have resulted in dispossession of resettled human communities of as many as one million to 16 million people resettled in Africa (Geisler & De Sousa, 2001) and 600,000 tribal people in India alone (PRIA, 1993). Historical displacements were often the result of individual protected area management policies and were poorly documented.

Criticism of historical evictions from protected areas have informed and improved resettlement policies (Agrawal & Redford, 2009; Lasgorceix & Kothari, 2009; West et al., 2006). However, landscape-scale studies which consider the wider impacts on conservation outside the boundaries of protected areas as well as the well-being of people after resettlement are few (Cernea & Schmidt-Soltau, 2003; Harihar, Ghosh-harihar, & Macmillan, 2014; Milgroom, Giller, & Leeuwis, 2014). Challenges to studying resettlement stem from historically poor documentation with consequent small sample sizes, standalone policies with little potential for replication of studies across geographies or peoples, and difficulties in defining as well as measuring human well-being.

Resettlement by definition affects both conservation and people, especially in human-dominated landscapes. Conservation acknowledges the importance of understanding human needs for natural resources around protected areas. Policies have compensated local populations for human-wildlife conflict, provided alternate livelihoods to alleviate human pressures from natural habitats, and implemented joint forest management (Goswami & Paul, 2012; Oldekop, Holmes, Harris, & Evans, 2016). However, the success of these efforts largely remains unclear, in part due to an overarching focus on conservation goals without enough emphasis on local needs for natural resources (Barua, Bhagwat, & Jadhav, 2013; Kumar, 2002; Naughton-Treves, Holland, & Brandon, 2005).

Additionally, whether resettlement truly alleviates pressures from conservation important areas or only moves them to another part of the landscape remains an open question. Resettlement from protected areas when viewed as a landscape-wide process can provide insights into policies that could achieve both landscape-scale conservation goals and well-being of resettled people. A growing body of research indicates that populations in proximity to protected areas are increasing (DeFries, Karanth, & Pareeth, 2010; Nagendra & Mondal, 2013; Wittemyer, Elsen, Bean, Burton, & Brashares, 2008). With increasing demands on natural resources in conservation landscapes, non-protected habitats face acute pressures for supporting people and wildlife. Resettlement of people from inside to outside protected areas potentially adds to these pressures.

India currently has a standardized resettlement policy to create inviolate zones for tiger conservation according to a national plan. The plan calls for management of inviolate habitat for

tigers (protected areas) and supporting multiuse zones (identified connecting corridor habitats). Mirroring the historical origins of resettlement from protected areas globally, India too has a contentious history of conflict and evictions from protected areas. Initially these forced displacements were hailed as a conservation success but were short lived, due to large scale tiger poaching and the consequent loss of tiger populations from Sariska (in 2004) and Panna Tiger Reserves (in 2005) (Narain, Panwar, Gadgil, Thapar, & Singh, 2005). The current conservation plan followed these drastic losses to enhance and improve tiger conservation efforts in the nation.

At the time of these losses to tiger conservation, India introduced the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act also known as the Forest Rights Act (FRA). The FRA, provides for the restitution of deprived forest rights across India, including both individual rights to cultivated land in forestland and community rights over common property resources. The current resettlement policy by India's National Tiger Conservation Authority (NTCA) Implementation of the NTCA policy provides an opportunity to study resettlement with relatively accurate records of where resettled households moved, a standardized monetary compensation and the potential for replication with large representative groups to study impacts in various landscapes across the country.

This dissertation examines resettlement from 2009 onward from Kanha National Park (KNP), one of the first and most well-known tiger reserves in India. KNP serves a vital role in maintaining tiger populations in central India where 40% of India's tigers reside. The park is of

high tourism value which supports the local economy (DeFries et al., 2010; Dutta, Sharma, McRae, Roy, & DeFries, 2015). The majority of the local communities around KNP are part of the "scheduled tribes" who fall under the provisions of the Forest Rights Act compensations.

KNP is situated within a network of protected areas within central India. More than 70% of the global tiger population lives in protected areas in India. The central Indian national parks hold approximately 40% of Indian tiger populations. However, management within protected areas alone cannot conserve tigers. Healthy genetic populations require tigers to be able to disperse from one population to another (Maldonado et al., 2013; Yumnam et al., 2014). Researchers have studied the various paths that tigers may use to navigate the human-dominated landscapes between protected areas, as well as multiple scenarios to plan for the future of tiger conservation (Dutta et al., 2015; Thatte, Joshi, Vaidyanathan, Landguth, & Ramakrishnan, 2018). KNP plays an important role as a refuge of tigers that allows for dispersal to nearby protected areas. Recent research implies that dispersing animals are moving across human-dominated landscapes with high tolerance for human disturbance (Krishnamurthy et al., 2016). The tiger population of Central Indian relies on dispersal between protected areas to exist in the long-term. Undirected resettlement of households from these National Parks could potentially influence the connectivity between parks if new-settlement locations cluster in important locations for tiger dispersal.

KNP managers historically displaced households during the establishment of the protected area in 1955. In the 1980s, the policy shifted to resettle households in a directed manner with some

provisions of land and relocation of entire villages to new locations. In 2009, the policy shifted once more to provide compensation with no directed location for resettlement. Like much of the global pattern, there exists little documentation of historical displacements and directed resettlement from KNP. In this dissertation, I only consider the resettlements from KNP under the current NTCA policy that began in 2009.

The goal of this dissertation is to study the resettlement impacts on people and landscape conservation goals around Kanha National Park (KNP) in central India. This dissertation builds on the excellent documentation of post resettlement locations of households by the Kanha Forest Department, previous knowledge of human-wildlife conflict within the KNP landscape (Karanth, Gopalaswamy, DeFries, & Ballal, 2012) and state of habitat connectivity between central Indian protected areas (Dutta et al., 2015).

In order to assess the impacts of resettlement on human well-being, this research focusses on food security as a quantifiable and meaningful measure of well-being. Food security is important to evaluate as a social goal in itself and provides a multidimensional measure of well-being compared to economic measurements. Globally, the number of undernourished people increased in 2016 (815 million) compared to 2015 (777 million). While it is worrying to note that food insecurity is growing, it is important to remember that compared to 2000 (900 million) the current numbers are markedly lower (FAO, IFAD, UNICEF, 2017). The historical focus on calories gained from improved rice and wheat yields, through the Green Revolution, has led to many gains in eradicating hunger, but increased concerns of nutritional diets, especially for rural

poor (Pingali, 2015). For many countries in the world, the current trends in food security and nutrition warrant scrutiny as significant challenges to end hunger by 2030 (Gödecke, Stein, & Qaim, 2018).

In India, the Green Revolution had great success in increasing production efficiencies and initiated consequent efficiencies in distribution. However, the gains from the Green Revolution did not translate to dramatic reduction of food insecurity and improved child health. India's gross domestic product (GDP) increased by 40 percent from 1998/99 to 2005/06 (seven years). However, the proportions of the population with stunted children and underweight children reduced by only around six percent and three percent respectively (Priya, Headey, & Kadiyala, 2012). The 'India Enigma' is this disconnect between this increased GDP and continuing food insecurity characterized by child stunting and undernutrition. In India, agrarian small-holder farmers are the largest proportion of the population, suggesting the recorded disconnect between increased GDP and food security is in a large part a disconnect between increased agricultural production and food security (Vicziany & Plahe, 2017).

Studying the four pillars of food security has shed some light on the ‘India Enigma’ by assessing the availability of foods, access to available foods, the capacity to use accessed foods and the stability of these aspects. For example, in India, understanding sources of bioavailable iron, zinc and calcium in diets, or the lack thereof, can have large impacts for public health outcomes as these are prevalent nutritional deficiencies with acute impacts on maternal health and child health (Kavitha, Soumitra, & Padmaja, 2016; Priya et al., 2012). Dietary intake is one important

aspect affecting nutritional outcomes for vulnerable populations. Additionally, studying food security sheds light on associated problems of the lack of sanitation and poor water quality that lead to vulnerable poor communities not being able to use the foods that they are able to access from their livelihoods. For example, anemia in India is a major public health problem and researchers attribute 20% of maternal deaths to it. Anemia affects more than half of women, as well as children (below 5 years of age) of the country's population. Poor subsections of the population are particularly vulnerable to anemia due to a complicated interconnected system that reduces availability, access and utilization of foods high in iron. Deficiency of iron is the most common cause of Anemia, but reliance on rice and wheat as staple cereals in diets reduces the physical availability of iron from the main foods consumed (Ruth DeFries et al., 2018). Additionally, bioavailability of iron is highest in meats (heme-iron) that are limited due to the prevalence of plant-based diets in India. Other factors contributing to anemia are poor sanitation and hygiene as well as diseases such as malaria, hookworm and some inherited disorders. Infections and inflammation impede iron absorption (utilization by an individual). Finally, dietary interactions reduce the bioabsorption of iron, especially prevalent in Indian diets (KM & Iyengar, 2009). One path to increase nutrition in diets has long been to increase production diversity. Recent studies point out that production diversity in small farms might be less effective than enhancing market access for better nutrition outcomes, which in turn influences wider aspects of well-being (Fanzo, 2017; Pingali, 2015; Sibhatu & Qaim, 2018).

In the KNP landscape, food security ties together changing agrarian livelihoods and natural resource use. In Chapter 2, coauthors and I explore the food security of resettled households at their new settlement locations. We include comparisons with non-resettled neighbors as valid,

pre-resettlement control households within KNP are impossible to survey. Additionally, from a landscape management perspective, the comparisons with non-resettled populations provide a useful baseline to assess the impacts of resettlement on household food security with inferences for post-resettlement interventions.

In Chapter 3, coauthors and I expand on the analyses of household food security from Chapter 1 to understand the role of natural, social and financial capitals in household livelihoods associated with higher food security in the KNP landscape. We use the five capitals model for sustainable development to reflect components of a human-nature coupled system. The five capitals model for sustainable development has only recently been used to address management within landscape systems as data have improved to allow for such analyses (Goswami & Paul, 2012; Hua, Yan, & Zhang, 2017).

To assess the impacts of resettlement on landscape conservation goals, coauthors and I illustrate how resettlement patterns might affect natural resource use in wildlife corridors and human-wildlife conflict risks. In this final chapter (Chapter 4), we use previous knowledge on corridors in the central Indian region and human-wildlife conflict around KNP. The analyses indicate livelihoods that might alleviate both natural resource use and risks of HWC in the KNP landscape. We answer whether resettlement truly alleviates human pressures from conservation habitats or if these pressures have been moved out of KNP into critical wildlife corridors.

I hope to demonstrate that interdisciplinary studies of resettlement impacts are possible and useful to both managers and scholars. The methods used in this dissertation have the potential for replication across other landscapes varying in geographic, ecological and social contexts, and especially in India under the current standardized resettlement policy.

CHAPTER 2 - CONSERVATION RESETTLEMENT AND HOUSEHOLD FOOD SECURITY: AN EXAMPLE FROM KANHA NATIONAL PARK, INDIA.

Amrita Neelakantan, Ruth DeFries, and Jessica Fanzo

Abstract

Conservation efforts have moved millions of people out of protected areas around the world since the 1970s, yet empirical data on their well-being after resettlement is sparse. Here, we examine the food security of approximately 600 households' post-resettlement from Kanha National Park (KNP) in central India between 2009 and 2014. We compare food security of resettled households with comparable non-resettled households through 1733 and 1786 surveys respectively, conducted over three seasons within one year. We measure food security using food consumption scores, coping strategies index and household hunger scale. Resettled households follow the same geographic pattern of household density as non-resettled households in terms of distance from built-up areas and markets. Results indicate that resettled households are comparable to their non-resettled neighbors in food consumption scores (FCSs) with very few reports of moderate or severe hunger across all our surveyed households. However, food insecurity is high in the landscape, with over 80% of households reporting poor or borderline FCSs. Additionally, in the monsoon season FCSs drop and resettled households use coping strategies more frequently than their non-resettled neighbors. Non-resettled households that have multiple crops per year were positively associated with FCSs, but resettled households FCSs were not associated significantly with multiple cropping. Accruing assets, diversifying incomes from non-labour avenues, increasing and maintaining village level food resources would alleviate food insecurity for resettled households. We conclude that resettlement does not create inequalities between resettled and non-resettled households in terms of distance to markets and

food consumption in the KNP landscape. Currently coping strategies are keeping hunger at bay but interventions can provide respite, particularly in monsoon season, from food insecurity for all households in the KNP landscape.

Introduction

Conservation-related resettlements trace back to the establishment of Yellowstone National Park in 1872 and spread rapidly with fortress management policies to conserve endangered species habitats. Protected areas cover more than 12% of the earth's terrestrial surface, a recognized conservation success, but have displaced millions of people from these areas (Brooks et al., 2004; Vaccaro, Beltran, & Paquet, 2013; West & Brockington, 2006). However, there are few estimates of the number of people displaced from protected areas. In India, the Society for Participatory Research in Asia (PRIA 1993) estimates that the establishment of protected areas displaced more than 600,000 tribal people. Geisler and De Sousa (2001) estimate that between one million and 16 million people were displaced across Africa. In response to the extensive critique of the dispossession of people due to conservation policies, various organizations and governments have addressed the dispossession of resettled people by establishing more inclusive management schemes (Cernea & Schmidt-Soltau, 2006; Kumar, 2002; West et al., 2006). However, studies of the trade-offs and synergies between biodiversity conservation and the well-being of people often find conflicting and complicated results usually explained by local context (Reardon, Lansing, Vosti, & Food, 1995; Sunderlin et al., 2005). Empirical research on the well-being of displaced people constitutes a small but growing literature and has been challenged by small samples sizes and uncomparable methods (Harihar et al., 2014; Kabra, 2009; Karanth, 2007; Zahran et al., 2015).

Understanding the impacts of conservation-related resettlement on people requires meaningful measures of human well-being. While income and assets-based metrics do provide information on human well-being and remain some of the most frequently used metrics, they do not capture many dimensions. For example, in low income households, income based metrics do not reflect livelihoods with goods or assets that have low economic value (for example – wild foods) and therefore provide inaccurate measurements of well-being (Bharucha & Pretty, 2010). More composite metrics such as the Quality Of Life measurements or the Human Development Index include more dimensions than income alone, but are difficult to apply across scales and are difficult to interpret (Gasper, 2007; OECD, 2011; Offer, 2000). Food security has recently gained favor as a measureable and multidimensional metric of human well-being by tying together livelihoods and natural resource use (Golden, Fernald, Brashares, Rasolofoniaina, & Kremen, 2011; Johnson, Jacob, & Brown, 2013; Jones, Ngure, Pelto, & Young, 2013).

In India, the current resettlement policy is explicit in its goal to resettle people to expand and maintain critical tiger habitats within 50 protected areas (Tiger Reserves) with detailed resettlement records and standardized compensations (GOI, 2008). The standardized monetary compensations allow households to move to locations where they purchase land (as opposed to previous schemes in which park managers displaced households to specific locations). The current resettlement provides an opportunity for a data rich study with potential for replicability across the country. Most importantly, India is a megadiverse and high human density country which mirrors the socio-economic and conservation realities faced by many nations with intense competition for natural resources (Bawa, Joseph, & Setty, 2007; Garcia et al., 2010; Rodrigues et

al., 2014). Kanha National Park, recognized internationally for tiger tourism, is important for tiger dispersal allowing for healthy genetic diversity in the central Indian populations (Rathore, Dubey, Shrivastava, Pathak, & Patil, 2012). The government of India recently recognized the efforts of the KNP's forest department with an award for their documentation and implementation of the current resettlement policy.

Specifically we explore food security at resettled households compared to their neighbors at their new settlement locations across the Kanha National Park landscape to answer the following questions:

1. Where are households resettled from the park relocating in relation to food availability?
2. Do resettled households have comparable Food Consumption Scores (FCSs) to their non-resettled neighbors?
3. Are resettled households able to cope in times of food scarcity and are their coping strategies similar to their non-resettled neighbors?
4. What livelihood strategies are associated with FCSs across resettled and non-resettled households?

Study Site

Kanha National Park (KNP) (22.3333° N, 80.6333° E), established in 1955, is one of India's most well-known Tiger Reserves. KNP is approximately 940 km^2 in area, with a multi-use buffer of approximately 1005 km^2. Mixed deciduous forests and grasslands form the typical vegetation and support populations of tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sambar (*Cervus unicolor*), chital (*Cervus axis*), barasingha (*Cervus duvaucelii*) and

gaur (*Bos gaurus*) (DeFries et al., 2010). KNP is only habitat for the endemic hard hoofed subspecies of barasingha (translocation to other protected areas with suitable habitats began in 2015) (C. P. Singh, Chauhan, Parihar, Singh, & Shukla, 2015). Additionally, KNP is central to tiger conservation in the region, if not globally, as a crucial habitat for genetic connectivity between tiger populations (Dutta et al., 2015). Large mammal populations (of prey species and predators) inhabiting the central Indian forests use forest corridors and move between protected areas, including Kanha National Park, Pench National Park and Achanakmar National Park (Fig. 1). Most of these corridors usually are located in topographically higher reaches of the region, with underlying rocky soil. Human populations surrounding KNP are primarily rural poor and include many scheduled tribes and castes.

Human population densities range between 182–195/km^2, and livestock densities range between 65–79/km^2 in the districts adjoining park boundaries (DeFries et al., 2010). Most households are agrarian and purchase food from local weekly markets. Agrarian households in this landscape are heavily dependent on the monsoon season as their main growing season and most irrigation is rain fed. The seasonal differences in livelihood strategies is likely to affect all aspects of rural living including food security. In the study region there are three seasons annually – summer (April - June), monsoon (July - September) and winter (October – March). Summers are hot and dry, monsoons are largely responsible for the annual precipitation with winters being cool and dry. Human livelihoods around the protected area rely on seasonal commercial and subsistence forest goods, including a heavy year-round reliance on forests for fuelwood (nearly 100% in this area compared to the 77% national average) and cattle grazing (Census of India, 2011).

As in many other protected areas, the park management displaced villages, to conserve habitats within protected areas, in the 1970s and then again in 1980s with compensations of land and financial aid (Lasgorceix & Kothari, 2009). The National Tiger Conservation Authority (NTCA) identified habitats and a conservation strategy to increase the number of tigers in India by creating inviolate core areas in tiger reserves across the country. In India, protecting habitats for wildlife range from inviolate habitats to multiuse habitats. Wildlife sanctuaries and national parks have stricter protection, while biosphere reserves, private conservancies and community protected lands might have varying levels of protection or human use. Tiger reserves can be both national parks and wildlife sanctuaries that are critical to tiger populations in the country and globally. To create inviolate core habitats, the NTCA approved a standardized protocol in 2006 that follows guidelines found in the National Resettlement and Rehabilitation policy (2007). This policy includes voluntary resettlement of households with monetary compensation, an option that is most common in practice in KNP (see Results). The current policy is in contrast to historical evictions in the 1970s and 80s from KNP in that it is not directed, provides standardized financial compensations and households can move to areas in the landscape where they can procure land. Resettlement remains a contentious conservation policy due to implementation of conflicting goals – to create inviolate habitats for wildlife while upholding the legal rights of human communities within protected areas (Kashwan, 2013; Sekar, 2016; Shahabuddin & Bhamidipati, 2014). The NTCA policy highlights changes in resettlement policy in response to criticisms of historical evictions from protected areas. From 2009 onwards, managers of KNP resettled approximately 850 households under the NTCA 2006 resettlement protocol, with standardized monetary compensations to household on the basis on number of adults. Not all households resettled at the same time - with some leaving in 2009, others as recently as 2013.

We consider only the resettled households from 2009 onwards to minimize the effects of unknown confounding factors from the previous resettlement programs of the 70s and 80s.

Methods

Scope of study: We quantitatively address outcomes of resettlement for human well-being using food security as a tractable and multidimensional metric. We explore patterns of food security across the landscape by surveying 1150 households three times in one year (2015) (IRB protocol number AAAN5603, exemption subsection 45CFR46). Our research intentionally does not compare households inside (pre-resettlement) to those who have moved outside (post-resettlement) of the park as no households remained inside KNP core at the time of study period or thereafter. The current National Tiger Conservation Authority (NTCA) policy for resettling households is clear that livelihoods are no longer viable within protected area boundaries and the forest department has placed many restrictions on resource use. Moreover, a reversal of the policy is not likely, suggesting that research can most usefully contribute through improved understanding of the impacts post-resettlement. We focus our analyses on household food access measurements, but provide information on pertinent landscape wide features that underpin food access – for example weekly markets, forest cover and kitchen gardens.

Sampling of non-resettled households: We surveyed non-resettled households at the villages where resettled households are now located to form a useful and appropriate baseline in our comparative analyses. Such an approach has found favor in comparisons when true controls are impossible to survey (Mukherji, 2013; Wilmsen, 2016; Xi & Hwang, 2011). The field assistants used the established social science method of picking every seventh house in a random walk

method using a coin toss to change direction. This was necessarily flexible to be able to sample non-resettled households in villages of different shapes and sizes. The number of such selected non-resettled households in each village follows the distribution of resettled households across the survey villages. In the case of one or two resettled households in a village, we survey three or five non-resettled households to ensure a sensible baseline. We surveyed the same households each season for resettled and non-resettled households, unless we could not locate household members in a given season. In the case of household members not being available for survey, we omitted the household from our survey if it was a resettled household but sampled another household if the survey household was for our non-resettled location specific baseline.

Sampling design and total survey effort: We surveyed approximately 600 resettled households from KNP under the current resettlement policy and approximately 550 non-resettled neighbors. The KNP forest department provided us data to locate all 850 of the resettled households at their new settlement locations across more than 157 villages across five districts of the two Indian states – Madhya Pradesh and Chhattisgarh. Within districts there are administrative units called tehsils that we use in our study to more accurately draw comparisons between resettled households and local populations. The drop in the number of resettled households in our surveys (from 850 to 600) is predominantly due to households merging when resettling outside of the park as well as a few households (<10%) that we could not locate.

We carried out surveys in three seasons to capture seasonal dynamics of food security and livelihood strategies in summer, monsoon and winter (May 2016 – January 2017). To measure the remoteness of survey locations we calculated forest cover per available capita, distance to -

built-up area, highway, closest market, river and the core forest of Kanha National Park. We conducted semi-structured interviews, at each survey household, to collect data on socio-economic status, food access measurements and interactions with forests. In total, we conducted 1332 surveys in summer, 1066 surveys in monsoon and 1122 surveys in winter. To conduct this extensive survey effort we employed 12 to 14 field assistants each season for approximately three to four weeks.

Food security metrics: We define food security in our study according to the four pillars of food security: availability, access, utilization and stability (Fig. 2). We use validated standardized multi-dimensional metrics that are scale appropriate (measured at the household level) with appropriate recall time to assess food security in the KNP landscape (Jones et al., 2013; Leroy, Ruel, Frongillo, Harris, & Ballard, 2015). To measure availability we measured produce and prices in markets across the landscape as well as asked about forest foods in semi-structured interviews. We used the Coping Strategies Index (CSI), the Food Consumption Score (FCS) and the Household Hunger Scale (HHS) to measure access (or lack thereof) to foods at the household level (D. Maxwell, Coates, & Vaitla, 2013) (Fig. 2). We measured utilization by recording responses to standardized queries on hand washing practices, child health and sanitation facilities. Finally, to measure stability we surveyed households three times in a year to capture seasonal variation and recorded incidence of shocks to the households. The field teams surveyed markets to gather baseline data on location-specific food availability with prices from two vendors wherever possible. Market data is key to discern the physical availability of foods across the landscape (Appendix 1). We focused on quantifying food access using metrics of diet diversity and the behaviors associated with coping in times of food scarcity. We acknowledge

that our measurements focus on the outcomes of household access resulting in recorded FCSs, CSI and HHS scores instead of direct measurement of the many aspects of accessing resources (Milgroom et al., 2014; Ribot & Peluso, 2009). Instead, we use response on some of these aspects of accessing resources in our models explaining patterns of FCSs.

The FCS and CSI are weighted scores based on the food groups consumed and coping behaviors exhibited in the last seven days in the surveyed household respectively (D. G. Maxwell & Caldwell, 2008; World Food Programme, 2008). We use the cross-culturally validated Household Hunger Scale (HHS) in our study to categorize households with - 'little or no hunger' (0-1), 'moderate hunger' (2-3) or 'severe hunger' (4-6). The HHS is calculated by recording the frequencies of severe behaviors in times of food scarcity, recalled over 30 days prior to the survey (Ballard, Coates, Swindale, & Deitchler, 2011). Categorization of the coping strategies as mild, moderate and severe were validated in focus groups before undertaking the surveys (Appendix 1). The FCS and CSI can together provide information on food quality and access, but the HHS provides more accurate measures of high levels of food insecurity (Ballard et al., 2011). For more details on focus groups that informed our choice and use of food access metrics please see supplemental information of this study (Appendix 1).

Data analyses: We used propensity scoring and visual inspection of all measured variables to ensure that our sampled non-resettled households provided a comparable baseline for surveyed resettled households. We used the following variables in our propensity scoring analyses: land owned, assets, shock incidence, winter crop types (count data – proxy for quality of land), winter crop (y/n – quality of land), years of education, number of adults, number of children, number of

relatives in vicinity, tribe and caste (categorical), and percent of wheat crop sold. We found that all variables used in analyses had balance by visually inspecting the distributions for resettled and non-resettled households separately. Although common practice to test for balance in a study design, we find that propensity scoring in large socio-economic datasets with many reasons for variability are likely to be too stringent if using too few variables and strict one-to-one matching. Thus, we find that some non-resettled households remain unmatched due to one-to-one matching without replacement, likely due to the heavy penalties for small differences (Appendix 1). Additionally, because all households have moved out of KNP no characteristics make a household more or less prone to resettlement.

In the KNP landscape, households buy foods from weekly markets and therefore restock each week for fresh vegetables, meats and staples. For availability of market items and their prices, we visually compared market checklists as most markets in the landscape have the same produce with similar prices as found in previous pilots (Appendix 1). We also asked respondents about consumption of forest foods, kitchen garden produce and measured forest available per capita at each new settlement location to measure supplementary sources for local food baskets. The weekly cycle of accessing markets in the landscape also influenced our choice of metric to measure diets at households – we deliberately chose the food consumption score (FCS) as it too has weekly cycle of recall.

We compared means of food access metrics (FCS, CSI and HHS) to ascertain if resettled households were food secure in comparison to their non-resettled neighbors. To understand if resettled households and non-resettled households had similar access to food we compared them

using standardized thresholds for adequate, borderline and poor FCS (World Food Programme, 2008). We used t-tests to find significant differences in food access between resettled and non-resettled households in each season – summer, monsoon and winter. We used ANOVAs and the Tukey HSD post-hoc tests to find significant differences in food access measurements (FCS and CSI) between resettled and non-resettled households within administrative regions (tehsils) in each season. We were also interested to explore livelihood strategies associated with household food access across the landscape, and modeled socio-economic data collected as each household to explain our overall distributions of FCSs in which CSIs were a determinant variable.

We used Euclidean nearest neighbor distances to find distances between household locations and nearest road, border of protected area (KNP core), market and built up area. We used existing GIS layers of roads, protected area borders, built up area and our GPS locations of markets (ISCGM, 2007b, 2007a). We also created buffers of four kilometers around each household GPS point and calculated forest cover within the buffer as number of pixels of forest cover (European Space Agency, 2012).

To understand patterns and associations in our data we used cluster analyses (ClustVis PCA), random forests and mixed effect models. We explore clustering in our data with all variables used in subsequent models using ClustVis an R package based online clustering tool with unit variance scaling and singular value decomposition (SVD) with imputation for Principal Components Analyses (PCA) (Metsalu & Vilo, 2015). In our PCA, we did not use resettlement specific variables (residence time, number of neighboring resettled households and origin village) as the results would be inaccurate due to arbitrary values assigned to non-resettled

household data points. We used random forests and mixed effect models to understand if resettled and non-resettled households have different characteristics or livelihood choices associated with food access measurements. We used random forests as a data partitioning algorithm to point to important variables associated with food access in the KNP landscape (Appendix 1). We used mixed effect models to evaluate important variables, identified in random forest analyses, to understand linear associations with FCSs resettled and non-resettled households separately. We included two random effects in our models for local administration (tehsil - for all households) and origin village (only when modeling food access in resettled households), as we expect the origin village and local administration to have effects on food access that could be important but unquantifiable. We included geographic and socio-economic variables recorded at each household as fixed effects when modeling household food access (Appendix 1). Using two methods to explore household choices and characteristics that are associated with food access measurements allow for more nuanced inferences and confirm the most important variables associated with food access in our analyses. We standardized all determinant variables used in mixed effect models to ensure that the unit of measurement does not have an impact on our results, and their consequential interpretation. In our comparisons of means, we did not transform or standardize our data. We conducted all statistical analyses using the software R (http://www.r-project.org) and QGIS 2.10.0- Pisa (Quantum GIS Development Team, 2015, qgis.os-geo.org).

Results

1. Where are households resettled from the park relocating in relation to food availability?

Resettled households have predominantly moved into existing villages in similar proportions to non-resettled human densities across the KNP landscape (Fig. 3). Out of 850 households resettled, only four left the landscape to two cities (Bhopal and Durg). As no households remained within KNP at the time of our surveys and thereafter, we compare resettled households to their non-resettled neighbors at the new settlement locations. Most households (resettled as well as non-resettled) are located within six to seven kilometers of a built up area. No resettled households involved in our study were further than 11 kilometers from their closest built up area. We compared proportions of resettled households to their surveyed non-resettled neighbors as well as total village populations across our study area, our measure of comparison was Euclidean distances from the closest built up area. Resettled households have remained closer to KNP when compared to all non-resettled households spread across the study tehsils and forest cover diminishes with distance from KNP (Appendix 1).

Additionally, households in the landscape around Kanha typically access the bulk of their foods from weekly markets at their village or a neighboring village (See methods and Appendix 1). Thus, resettled and non-resettled households have similar availability of food across the study region.

2. Do resettled households have comparable FCSs to their non-resettled neighbors?

Resettled households reported similar Food Consumption Scores when compared to their non-resettled neighbors across all three survey seasons, except in Baihar tehsil in summer. The year round average FCS for resettled households was 34.49 and for non-resettled households was 34.36 (p-value = 0.68). In our study, households consume food groups in similar frequencies with cereals, tubers and pulses making up more than 65% of the total FCSs across seasons and locations (Fig. 4). Thus, diets in this region predominantly consist of high proportions of storable staples – cereals, tubers, and pulses. In Baihar tehsil during summer, resettled households (mean FCS = 36.24, n=122) had, on average, five points higher FCSs than non-resettled households (mean FCS = 31.13, n=147) (p-value = 0.001).

While resettled households consume food groups in similar frequencies to non-resettled households (apart from Baihar tehsil in summer), we find that approximately 80% of all households have inadequate levels of food consumption (borderline or poor) (Fig. 5 (a)). Among all the surveyed households, approximately 20% have poor FCSs. Resettled households and non-resettled households have the same proportions of households being able to access acceptable, borderline and poor levels of FCSs, with a seasonal negative affect in monsoon. The number of households reporting poor FCSs rises to approximately 30% in monsoon (Fig. 5 (a)). Poor FCS households predominantly consume lower frequencies of non-staple food groups (vegetables and meats) (Fig. 5 (b)).

All households predominantly access food through market purchases or self-provisioning (>90%) year round. Only a handful of households forage for vegetables (1-7 households across seasons) and hunt (2 households in monsoon) (Appendix 1). Across seasons and resettlement status, we recorded only three instances of severe hunger and only 78 out of all 3519 household surveys reported moderate signs of hunger. Only one case of severe hunger was reported at a resettled household.

3. Are resettled households able to cope in times of food scarcity and are their coping strategies similar to their non-resettled neighbors?

Resettled households had higher CSIs (mean = 3.29) than their non-resettled neighbors overall (mean = 2.58) (p-value = 0.0004). Across seasons, we found that the higher overall CSIs at resettled households were due to the significantly higher CSIs in monsoon at resettled households when compared to their non-resettled neighbors (means 4.54 and 3.18 respectively, p-value = 0.001). Resettled households were similar in CSIs to their non-resettled neighbors in summer (p-value = 0.57) and winter (p-value = 0.1). In monsoon, CSIs of resettled households were significantly higher than CSIs of non-resettled households across two administrative units (Baihar and Panderia). Additionally, resettled households reported higher CSIs than non-resettled households in winter in Baihar and in summer in Panderia (Appendix 1). Moreover, the higher monsoon CSIs in resettled households are due to higher frequencies of all coping behaviors employed by households (Fig. 6).

4. **What livelihood strategies are associated with FCSs across resettled and non-resettled households?**

Our results of modeling livelihood aspects associated with resettled and non-resettled households highlight that increasing asset index values were positively associated with FCSs (measurement of household food access) across all seasons. Owning poultry and cattle were positively associated with household FCSs, but not across every season for both resettled and non-resettled households. We found that CSIs are positively associated with FCSs, except in summer. Additionally, entering the formal job market with salaried incomes was positively associated with FCSs for resettled and non-resettled households. In contrast, labour incomes were most often negatively associated with FCSs in resettled and non-resettled households (Table 1, for model result details see Appendix 1). The similarities in livelihood strategies between resettled and non-resettled households are further confirmed by our PCA results where resettled and non-resettled households overlap in variable space almost entirely (Appendix 1).

Apart from the above livelihood associations with FCSs, resettled households relied on landscape resources (in monsoon and winter) while non-resettled households relied on winter cropping to attain similar FCSs. Overall, resettled households with livelihood choices that used resources from home gardens, increased reliance on forest foods and who had more relatives in the area were positively associated with FCSs. In contrast, non-resettled households with choices leading to owning more land and winter cropping were positively associated with FCSs (Table 1).

Interestingly, distances to markets were negatively associated with resettled households in summer and winter, while distances to built-up areas were negatively associated with non-resettled households only in monsoon. Finally, resettled households also exhibit a temporal aspect with months since resettlement being positively associated with FCSs in winter.

Discussion

The key objective of our study was to explore post-resettlement comparisons of food security between resettled and non-resettled households in the KNP landscape. Non-resettled neighbors at the new settlement villages provide a baseline to compare food security measurements and livelihood strategies.

With implementation of the policy in KNP to compensate households after finding land to purchase, resettled households move to areas that are similar in terms of food availability and economic opportunities as surveyed non-resettled households. We recognize that alternate implementation of resettlement policies might result in different outcomes. In our dataset, only four households out of 850 left the landscape and we were unable to survey them. Resettled households were located in similar proportions to non-resettled populations, in terms of distance to built-up areas across the study region. Additionally, we found that differences in food security between resettled and non-resettled households are not due to differences in physical availability of foods as all household predominantly buy produce from similar weekly markets. Households sometimes supplement market bought food stocks with produce from kitchen gardens. Households also rarely mentioned forests as sources for foods, forest foods consumed are bought

from markets in most cases. Our findings suggest that the current resettlement does not constrain resettled households in the remotest areas across the region in terms of livelihood opportunities as well as physical food availability. In contrast to previous historical displacements (see - Lasgorceix & Kothari, 2009), the current resettlement allows individual households to choose where to settle depending on land availability. The resulting patterns of resettlement mirror that of non-resettled populations.

Resettled households are similar in food consumption scores (FCSs) to their non-resettled neighbors, but more than 80% of all surveyed households report borderline or poor FCSs. However, very few households report hunger measured by HHS scores. Results suggest that the current resettlement leads to similar food consumption of resettled households when compared to non-resettled neighbors. However, monsoon season negatively affects resettled and non-resettled households' FCSs with the proportion of households with poor FCSs rising to 30% of all households surveyed in monsoon. As consumption frequencies drop across more nutritious food groups we find that households mainly use consumption of less preferred foods and food on credit (or in lieu of work) (D. G. Maxwell & Caldwell, 2008). Although all households use coping strategies, on average they do so in frequencies of less than a day per week. Our findings suggest that coping strategies are the path to avoid hunger in the landscape and therefore are positively associated with FCSs in our model results. Efforts to improve food security, such as food subsidies or distribution, would be most effective during monsoon season.

Although food consumption outcomes are similar for resettled and non-resettled households, their livelihood strategies have a few differences. Resettled and non-resettled households with increasing assets and diversified incomes showed positive associations with FCSs. Households with incomes from poultry and agriculture had comparable positive associations with FCSs as salaried jobs. We suggest that gains from poultry farming might be an avenue for on-the-ground interventions that aid alleviation of poverty as well as food insecurity (Alders & Pym, 2009; Golden, Rabehatonina, Rakotosoa, & Moore, 2015). Apart from increasing overall economic wealth, there is a notable difference in the livelihood strategies of resettled and non-resettled households around KNP. Resettled households rely on landscape resources (tendu trade, gathering foods and home gardens) while non-resettled households predominantly rely on winter cropping to attain similar FCSs. The positive association of more relatives in the area for resettled households is also explanatory as a better social network to aid in coping strategies. Such an association was not significant for non-resettled households. We document these differences so that the results of our study can aid in tailored interventions to alleviate food insecurity more accurately and therefore more efficiently.

To increase overall wealth, an obvious but difficult application of our results would be to generate more opportunities for salaried jobs and making agricultural practices more profitable. Such an obvious result seems a moot point to discuss but we do so to ensure our results are not seen as a contrast of two separate livelihoods – resettled households with forest livelihoods separated from rural non-resettled households with more wealth driven livelihoods. Our results confirm that the reality is one where rural livelihoods predominantly feature wealth accruement and predominantly market bought foods regardless of being resettled and non-resettled

households. However, a clear result from our study is that diversifying incomes towards non-labour sources is positively associated with FCSs whereas households with only labour or labour in addition to agriculture incomes are negatively associated with FCSs. Daily wage labour is likely a desperate avenue for diversifying incomes and is therefore associated with households that have poor FCSs.

We found a few unexpected associations in our analyses between livelihood strategies and FCSs. Our study shows that owning more heads of cattle may not always be beneficial to a household. While our study shows both the positive and negative association was significant, further study on owning and maintaining cattle will aid in the mechanistic understanding of cattle as an asset as well as a liability. We also found that self-reported forest access has a positive association with FCSs in our study. A possible explanation is that access to forests provide for seasonal Tendu incomes and seasonal foods. Our results about using natural resources and forests for food security contribute to the growing body of research on linkages between food and forests (see - Bharucha & Pretty, 2010; Johnson et al., 2013; Sunderlin et al., 2005), adding empirical findings from KNP - a human-dominated protected area landscape. Additionally, most surveyed households report borderline FCSs and very likely use all available resources to attain economic wealth to increase market reliant household food access in the KNP landscape.

Results indicate that possible approaches to alleviate seasonal worsening of food security in the region during monsoon are: improved food distribution in monsoon; pilot studies on poultry farming for poor FCS households; and promote winter farming as a stable income from

agricultural crop land. A suggested study pilot is the employment of tourism related drivers and vehicles to ensure food aid or subsidized foods can be transported closer to households or workers in fields. Additionally, we suggest exploring low cost (economic and time) interventions such as home gardens and maintaining commons to allow poor and borderline FCSs households to access fresh vegetables more frequently.

Our study while collecting information on seasonal changes is a snap shot of each season over a single year (May 2015 – Jan 2016). The temporal scale of the study in terms of resettlement is due to households resettling at various times since 2009 under the same policy across the KNP. We also have no information on the few households that seasonally migrate as labour or have left the landscape altogether. We focus our analyses on food security and more specifically the quantitative aspects of food access but we acknowledge that to understand resettlement impacts there are many other aspects left to study, notably - qualitative and subjective well-being, mental well-being, and food utilization related to health status. Additionally, changes in food sovereignty of resettled households remain unexplored in our study, an aspect intrinsically linked to conservation-related resettlement (Jansen, 2015; Li, 2015; Patel, 2009; van der Ploeg, 2013). Longer temporal data than was possible in this study is required to understand changes in livelihood strategies and FCS along generational or decadal scales.

Conclusion

In the landscape around Kanha National Park (KNP), more than 80% of all households surveyed report poor or borderline food consumption scores and households use coping strategies to avoid

hunger. Food consumption scores and coping strategy index worsen in the monsoon season. Households resettled from KNP under the 2006 National Tiger Conservation Authority (NTCA) policy (GOI, 2008) generally settle into existing villages with distances to town comparable to the non-resettled local populations. Both resettled and non-resettled households access food predominantly from weekly village markets.

Although we cannot identify whether current food consumption is different than consumption prior to resettlement because households no longer reside in the park, we find that the current resettlement under the 2006 NTCA policy has not led to lower food availability or consumption for resettled households relative to their non-resettled neighbors around the KNP landscape. However, the livelihood strategies used to arrive at similar food consumption scores show seasonal differences in monsoon and winter. Food consumption scores (FCS) for resettled households are significantly positively associated with the use of landscape resources, namely forest foods consumed and foods from kitchen gardens. In contrast, FCSs for non-resettled households are positively associated with winter cropping, which generally requires fertile land and irrigation.

Our results suggest that increased opportunities for diversifying non-labour incomes could be effective to alleviate food insecurity for both resettled and non-resettled households in the KNP landscape. This result reinforces multiple studies that highlight livelihood diversification as a means for alleviating household food insecurity (Kabra, 2009; Mahapatra, Tewari, & Baboo, 2015). Our results for the KNP landscape suggest that access to forest resources is less critical

for food security than the ability to purchase food from local markets. While other studies indicate the importance of access to forests for food security in other landscapes (Baudron, Duriaux Chavarría, Remans, Yang, & Sunderland, 2017; Golden et al., 2011; Johnson et al., 2013; Reed, van Vianen, Foli, et al., 2017), we posit that the role of forests in food security is highly dependent on the local context and integration of households with markets. A general conclusion about the relevance of forests for food security cannot be applied to all landscapes.

Additionally, we suggest targeted interventions during monsoon when food insecurity peaks. Food security for resettled households, and their non-resettled neighbors, in the Kanha National Park landscape will be best achieved by integrating the poorer households into the economy with more opportunities, such as steady jobs and poultry farming, for higher incomes and seasonal stability. Managers for resettlement and rural development around KNP, and in other human-dominated conservation landscapes, might consider the importance of training for employment with steady incomes in future interventions.

At the national policy level, the NTCA can use the methods from our study to explore links between livelihoods and social goals in resettlement from tiger reserves across India that vary ecologically, geographically and culturally. NTCA has designated 50 tiger reserves spanning all regions of the country. Our study indicates the importance of detailed assessment of each situation and design of effective strategies for food security and well-being of resettled households that reflect the particular level of market integration, food availability in the surrounding landscape, and economic opportunities. While this study concluded that steady

incomes are highly relevant for food security in the KNP landscape, other landscapes around tiger reserves might indicate the need for access to forests or efforts to improve food availability.

Our study is contributes to the growing quantitative assessment of resettlement on human well-being measurements, tying together conservation and social goals (Harihar et al., 2014; Harihar, Veríssimo, & MacMillan, 2015; Snodgrass, Upadhyay, Debnath, & Lacy, 2016; Zahran et al., 2015). The study focusses on a human-dominated landscape surrounding a protected area, in contrast to other literature in which the landscape is less densely populated and less integrated with markets (Golden et al., 2011; Mainka & Trivedi, 2002; Sunderland et al., 2001). We use food security as a measurement of well-being because it is intrinsically part of rural agrarian livelihoods and an important social goal for vulnerable communities such as poor farmers. In regions of the world with acute land competition, such as India, assessments of conservation action will aid in developing guidelines for resettlement policies. Our study forms a data rich case study within landscape trade-off frameworks to reach multiple goals for people and wildlife (see DeFries et al., 2010; Duffy, et al., 2016; Milner-Gulland et al., 2014). We stress the importance of documenting resettlement and assessing metrics of post-resettlement well-being. Because pre-settlement controls are not likely to exist as a baseline, and because resettlement is a reality that is unlikely to change, an alternative comparison to assess well-being is comparison with comparable, non-resettled households in the landscape. The study of resettlement is integral to the conservation-development field, especially in protected area landscapes (Agrawal & Redford, 2009; Harihar et al., 2015; Lasgorceix & Kothari, 2009; Sekar, 2016). Our study provides a measurable, meaningful and replicable way to understand post resettlement dynamics across these landscapes where people and conservation are intricately connected.

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Figures and Tables

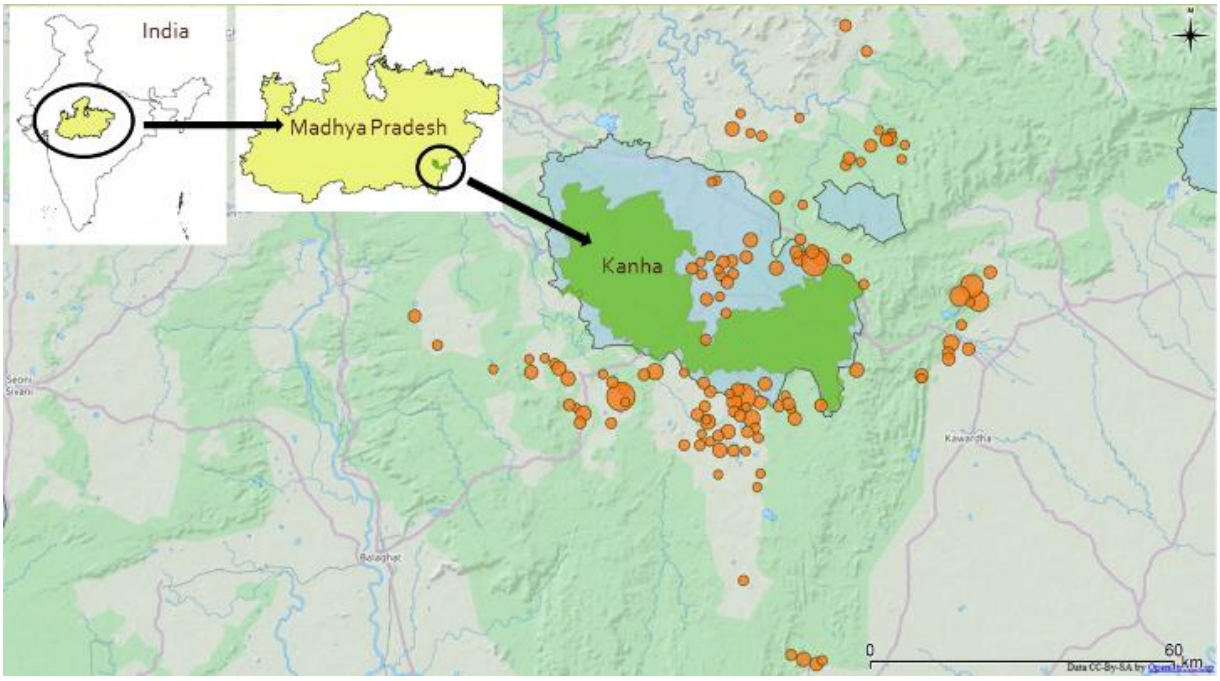
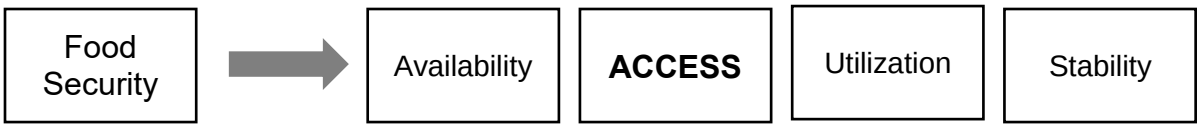


Figure 1: Study site and resettlement locations

KNP has a core (green polygon) with a multiuse buffer (blue around green polygon and satellite small blue polygon north of core). The non-protected forest corridors joining protected areas are on either side of Kanha National Park, boundary of Achanakmar National Park shown as incomplete blue polygon in top right corner of map. Orange circles indicate number of resettled households from KNP at their new settlement locations. Largest circles signify many households (around 32 to 40) settled at that village location and the smallest circles signify 1 to 3 households. Pink and blue lines respectively indicate roads and rivers. Inset maps show location of KNP in Madhya Pradesh state in central India.

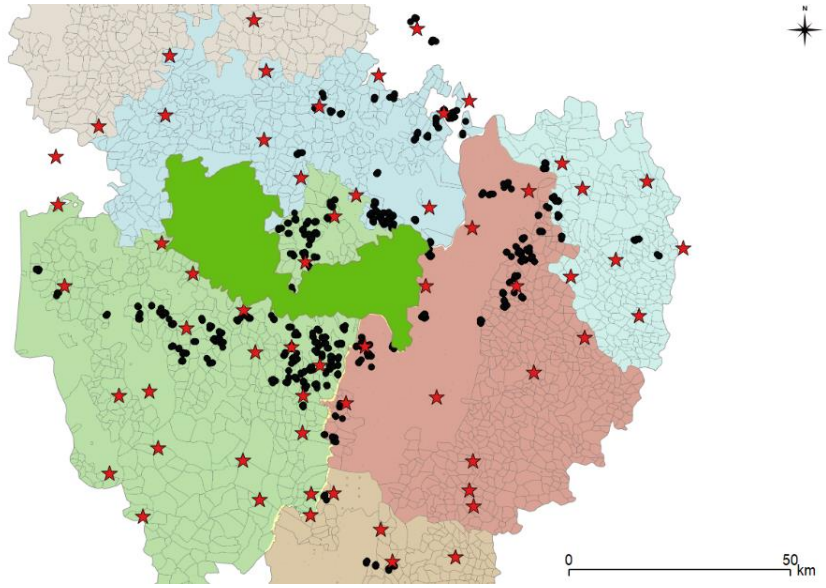


Metric Name	What it measures	Recall duration	Range of Values
Coping Strategies Index (CSI)	Frequency of 12 Behaviors * Weight	7 days	0 to 203
Food Consumption Score (FCS)	Frequency 9 Food Groups consumption * Weight	7 days	0 to >35
Household Hunger Scale (HHS)	Frequency of 1 situation (no food available) and 2 behaviors * Weight	30 days	0 to 6

Figure 2: Pillars of food security, focus on access with details of metrics used

Diagram shows the four pillars of food security. We used three standardized metrics to explore household access to foods available at their village location (Ballard et al., 2011; D. Maxwell et al., 2013; D. G. Maxwell & Caldwell, 2008; World Food Programme, 2008).

(a)



(b)

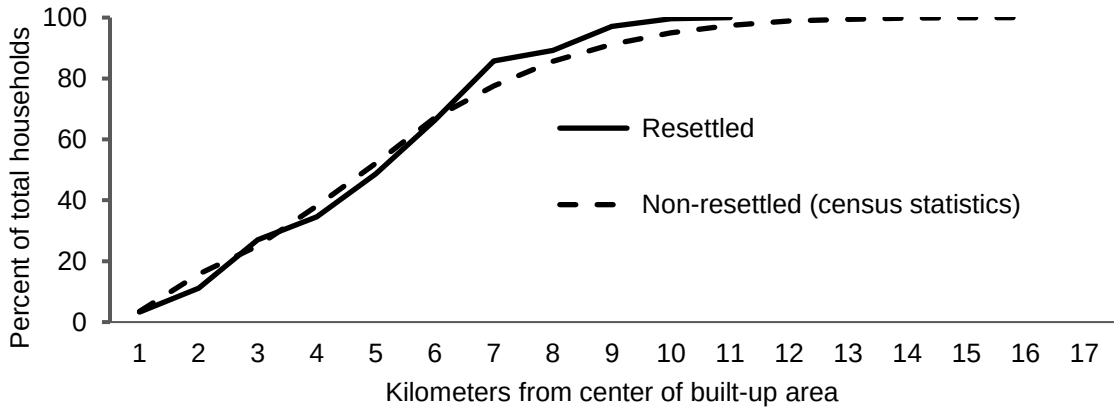


Figure 3: Locations of resettled households compared to non-resettled households from built up areas.

(a) Map shows locations of built up area (red stars), village boundaries color coded into administrative units (tehsils) and locations of resettled households (black dots) used to calculate Euclidean distances between rural populations and urban centers. (b) Resettled households proportionally mirror densities of non-resettled human densities across urban-rural transition in the KNP landscape (chart below map). In our study, resettled households were within 11 kilometers of a built up area.

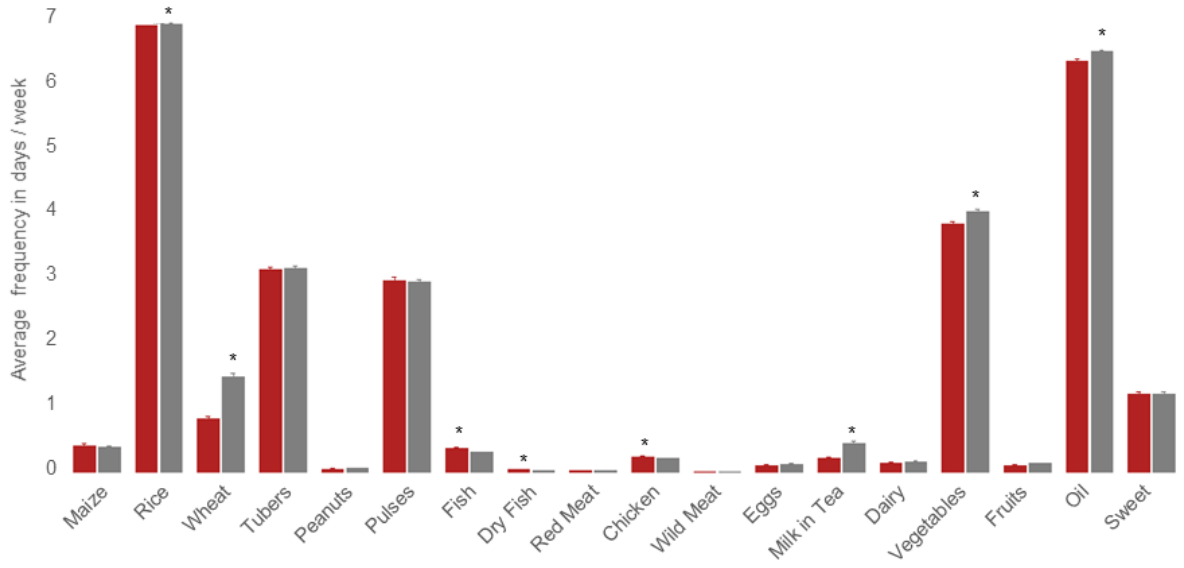
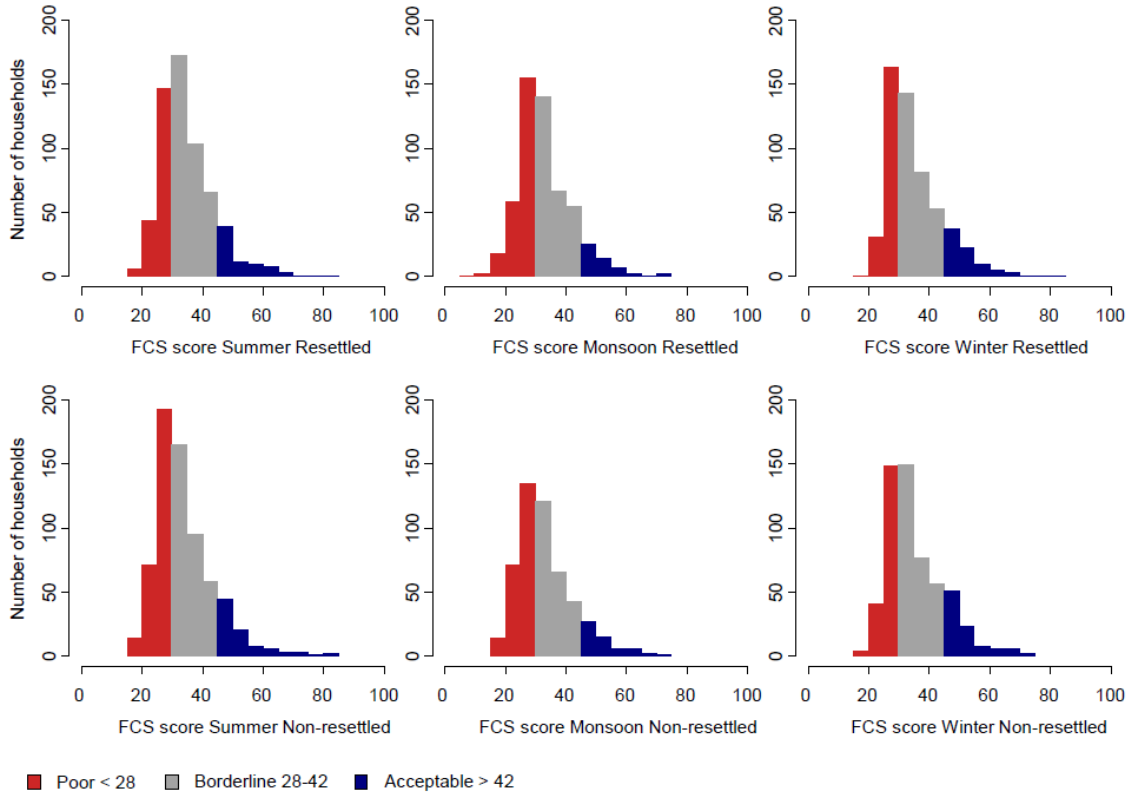


Figure 4: Resettled and non-resettled households show similar frequencies of food groups consumed.

Resettled (red) and non-resettled households (gray) show similar frequencies of food groups consumed. Frequency of consumption (days per week) is pooled across all survey seasons. * indicates $p<0.05$ when comparing resettled and non-resettled households in t-tests.

(a)


Number of households
0
50
100
150
200
0
20
40
60
80
100
FCS score Summer Resettled
FCS score Monsoon Resettled
FCS score Winter Resettled
FCS score Summer Non-resettled
FCS score Monsoon Non-resettled
FCS score Winter Non-resettled
Poor < 28
Borderline 28-42
Acceptable > 42

(b)

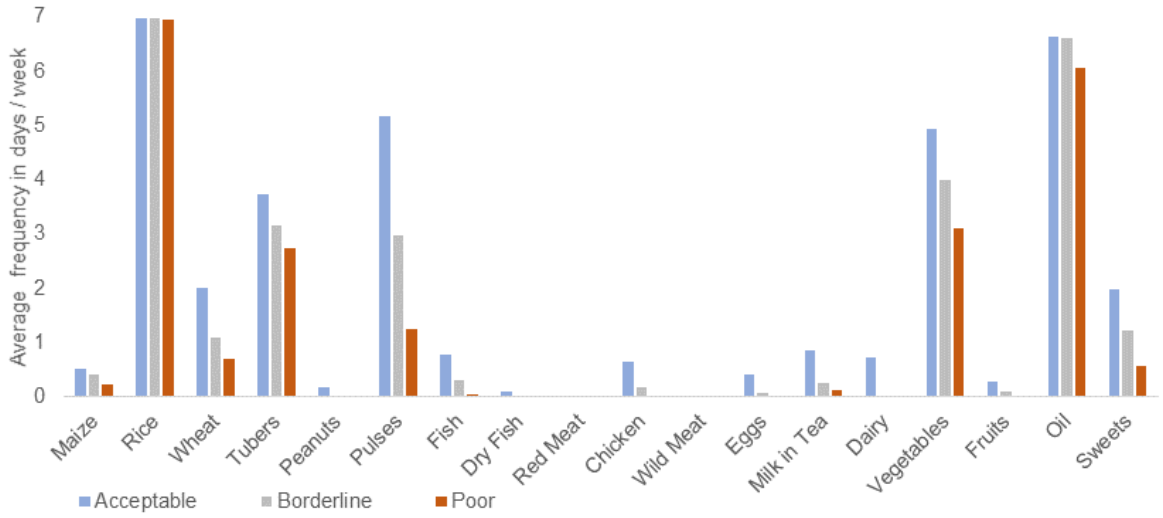


Figure 5: FCSs of resettled and non-resettled households across seasons and food groups

Overall, resettled and non-resettled households (a) have the similar proportions of poor, borderline and acceptable food consumption scores. Households with poor (red) or borderline (gray) FCSs reported diets dominated by staples (b) and with lower values of other food groups (b).

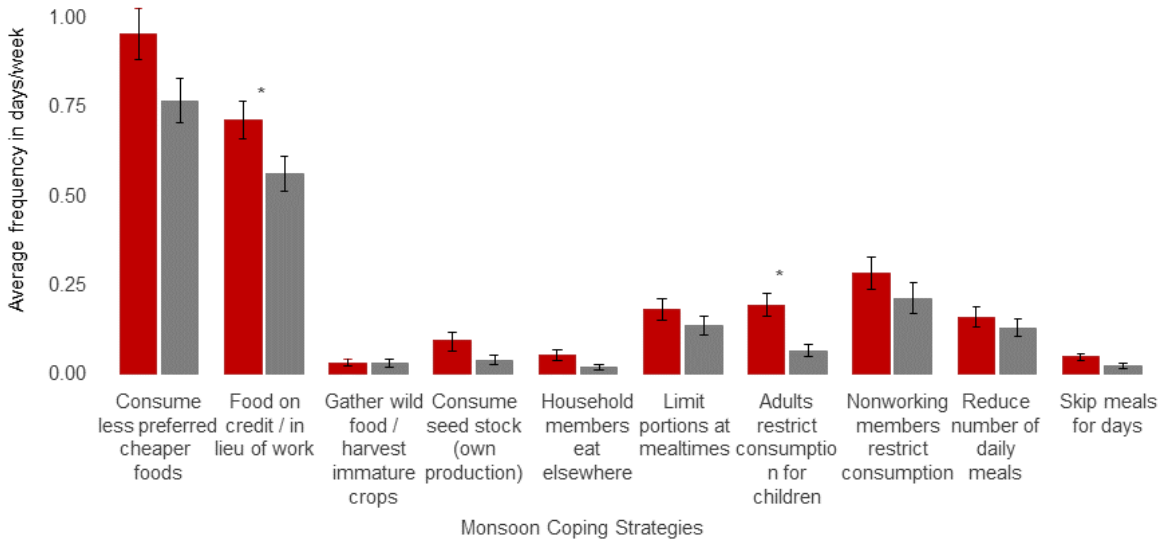


Figure 6: CSI of resettled and non-resettled households in monsoon.

Resettled and non-resettled household employ all coping strategies in monsoon, but resettled households use all of these coping strategies more frequently than their non-resettled neighbors.

* indicates $p<0.05$ in t-test comparisons.

Table 1: Variables with significant associations to FCSs for resettled and non-resettled households across seasons. Linear mixed model results with random effects of tehsil and origin village as categorical variables. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.'

	Summer		**Monsoon**		**Winter**	
Marginal R square	0.2	0.18	0.11	0.21	0.22	0.27
Conditional R square	0.21	0.19	0.13	0.21	0.22	0.27
Significant Determinant Variable	**Resettled Coefficient (SE)**	**Non-resettled coefficient (SE)**	**Resettled Coefficient (SE)**	**Non-resettled coefficient (SE)**	**Resettled Coefficient (SE)**	**Non-resettled coefficient (SE)**
FOR ALL						
Assets Index Score	0.18 *** (0.04)	0.21*** (0.04)	0.19 *** (0.05)	0.14 *** (0.04)	0.08 * (0.04)	0.23 *** (0.04)
Poultry (number owned)	0.08 * (0.04)	0.1 ** (0.04)		0.19 *** (0.04)	0.18 *** (0.05)	
Cattle (number owned)		0.11 ** (0.04)	0.16 *** (0.04)			0.18 *** (0.04)
Coping Strategies Index		-0.08 * (0.04)	0.13 *** (0.04)	0.2 *** (0.05)	0.26 *** (0.04)	0.15 *** (0.04)
Labour + agriculture incomes	0.3 *** (0.07)				-0.33 *** (0.08)	-0.26 ** (0.08)
Labour only income		-0.25 * (0.12)			-1 ** (0.32)	
Poultry + agriculture incomes	2.44 ** (0.87)					1.56 * (0.63)
Tendu Trade (people * days)	0.2 *** (0.05)			-0.11 ** (0.03)		
Forest Access self-reported: Yes	0.38 *** (0.09)	0.44 *** (0.09)		0.43 *** (0.1)	0.53 *** (0.1)	0.44 *** (0.09)

ONLY RESETTLED					
Job + agriculture incomes	1.85 *** (0.32)				
Cattle + agriculture incomes				-0.84 * (0.41)	
Cattle only income				-2.15 * (0.9)	
Forest Food types (count)		0.12 ** (0.04)			
Garden diversity item type (count)				0.07 * (0.04)	
Time since resettlement (months)				4.55 ** (1.62)	
Number of relatives in area		0.13 ** (0.04)		0.13 ** (0.05)	
Distance to Market	-0.07 '.' (0.04)			-0.07 '.' (0.04)	
ONLY NON-RESETTLED					
Job only income					1.16 ** (0.41)
Land owned (hectares)			0.17 *** (0.03)		
Count of Winter crops					0.14 *** (0.04)
% Wheat sold			0.11 *** (0.03)		
% Rice crop consumed					-0.14 *** (0.04)
Midday meals for children at school (days/week)		-0.1 ** (0.03)			
Distance to built-up area			-0.1 * (0.04)		

CHAPTER 3 - CONTRIBUTIONS OF FINANCIAL, SOCIAL AND NATURAL CAPITAL TO FOOD SECURITY IN CONSERVATION-INDUCED RESETTLED HOUSEHOLDS AROUND KANHA NATIONAL PARK

Amrita Neelakantan, Ruth DeFries, Eleanor Sterling, and Shahid Naeem

Abstract

The well-being of people living around protected areas is critical in its own right as well as for effective conservation, particularly in human-dominated landscapes. We examine the contributions of financial, social, and natural capital to household food access of 883 households around Kanha National Park (KNP) in central India over three seasons. We use regression trees and mixed effects models to identify associations between natural, social, and financial capital indicators and household food access. We find that food access is low in the KNP landscape with over 80% of households indicating lower than acceptable food consumption scores, with a further worsening in monsoon season. Financial capital (e.g. salaried jobs and proximity to towns for all seasons) is most prominently associated with higher food consumption scores. Moreover, households supplement incomes by converting social (e.g. "food in lieu of work or credit" in monsoon) and natural capital (e.g. sale of forest products in summer) to financial capital seasonally. Financial capital dwarfs contributions of social and natural capital around KNP, in contrast to other studies, which suggest that gains from natural capital are essential for well-being of people around protected areas. Management interventions enhancing human capital, such as kitchen gardens to supplement market-bought produce, could contribute to food security without high financial inputs. However, food insecurity in the KNP landscape primarily relates to the lack of financial capital. Food security of people around protected areas in other human-dominated landscapes is likely to be context-specific and counter to frequent assumptions particularly as livelihood strategies change with increasing economic opportunities.

Introduction

Over the last few decades, recognition has grown that effective conservation includes the needs of local populations and cannot succeed over the long term at the cost of local peoples (Garcia et al., 2010; Naughton-Treves et al., 2005). A foremost concern is the global protected areas network, the cornerstone of biodiversity conservation, which covers more than 12% of the earth's terrestrial surface. The expansion of protected areas has had quantifiable and large detrimental impacts on vulnerable human communities by restricting access to natural capital (ecosystem goods and services) (Brooks et al., 2004; Torri, 2011; West & Brockington, 2006). Forced displacements of peoples occurred during the creation of the world's protected area network and are widely recognized for their severe detrimental impacts on people (Büscher, Sullivan, Neves, Igoe, & Brockington, 2012; Cernea & Schmidt-Soltau, 2006). More recently, voluntary resettlement has acknowledged the restricted access to protected natural capital due to resettlement through compensations of land and financial aid (Agrawal & Redford, 2009). In addition to displacement, costs of restricted access to natural capital by protected areas to local people include restricted access to wild foods, bush-meat, and non-timber forest products (Coad, Campbell, Miles, & Humphries, 2008).

However, protected areas also provide many benefits to contiguous local populations. Studies on peoples' interactions with protected areas include well-documented gains from protected areas through climate change resilience, ecosystem services, and goods (Ruth DeFries et al., 2010; Golden et al., 2011; Rasolofoson, Hanauer, Pappinen, Fisher, & Ricketts, 2018; Reed, van Vianen, Barlow, & Sunderland, 2017). Protected area management can also alleviate poverty in local populations. For example, in Costa Rica there is evidence of ecotourism mechanistically

alleviating poverty (Andam, Ferraro, Sims, Healy, & Holland, 2010; Paul J Ferraro & Hanauer, 2014). However, wealth generated by protected areas in many landscapes is not distributed to local people, and even when wealth is distributed locally it is seldom equitably distributed (Daw, Brown, Rosendo, & Pomeroy, 2011; Kumar, 2002; Robinson, 2011).

Understanding the contributions of local resource pools (or capitals) to local livelihoods underlies the ability to meet the needs of local populations around protected areas (Ruth DeFries et al., 2010; McElwee, 2010; Oldekop et al., 2016; Persha, Agrawal, & Chhatre, 2011; Southworth, Nagendra, & Munroe, 2006; Zagoraiou et al., 2008). Studying local livelihoods as the reliance on and accumulation of different types of capital for well-being potentially overcomes the challenge of context-dependent results in forming generalizable trends (Villamagna & Giesecke, 2014). One framework to consider livelihood requirements and interlink them with multiple conservation and well-being goals is the five capitals model of sustainable development – including financial capital, social capital, natural capital, human capital, and physical capital (DFID, 1999; Villamagna & Giesecke, 2014). The five capitals model of sustainable development has been used to explore the direct and indirect reliance on natural capital by vulnerable households when evaluating the adaptive capacity and resilience of populations as well as gains from joint forest management (Goswami & Paul, 2012; Thulstrup, 2015). We use the five capitals framework to clarify associations between livelihood factors we measured and food access in the KNP landscape.

Natural capital provides benefits to people living around protected areas through goods (e.g., wild foods, bush-meat) and ecosystem services for agricultural production and human health

(directly or indirectly by conversion to other types of capital) (Golden et al., 2011; Johnson et al., 2013; Zhang, Ricketts, Kremen, Carney, & Swinton, 2007). However, recent research has also pointed out that the benefits of natural capital might not be as large or widespread as previously estimated (Wunder, Angelsen, & Belcher, 2014). Social capital on the other hand has recently been a focus of research and found to be more important for human well-being than previously recognized (Fischer & Chhatre, 2015; Ghazoul, 2007; Kumar, 2002). Finally, financial capital and political capital point to the importance of formal employment, increasing off-farm diverse incomes and agency. Very few studies evaluating the contributions of different types of capital within a single system exist. Studies that parse out the contributions of natural resources in comparison to other types of capital are key to understanding and managing modern requirements of local populations within these landscapes.

Food security as a measure of well-being in rural livelihoods ties together economic and non-economic types of capital used by a household, village or community (Mainka & Trivedi, 2002), particularly in biodiverse regions with vulnerable human communities who have traditionally relied on natural capital directly and converted natural capital to other forms of capital. We use food security in our study as a multidimensional aspect of well-being of people living around protected areas.

This study explores the contributions of natural, social, and financial capital to food security in the landscape surrounding Kanha National Park (KNP) in India. The central Indian region is globally well-known for tiger tourism and is critical to maintaining tiger populations with recent resettlements under a nationally standardized policy (GOI, 2008). The region mirrors the realities

of other human-dominated landscapes with conservation and development challenges – acute land competition for large infrastructure, conservation, and rural human populations. We address the following questions:

1. What is the status of food security in the landscape surrounding Kanha National Park?
2. How does food security in the landscape vary seasonally and spatially?
3. What are the relative contributions of natural, social, and financial capital to household-level food security?

Methods

Study site

Kanha National Park (KNP) (22.3333° N, 80.6333° E), established in 1955, is one of India's most well-known Tiger Reserves. KNP is approximately 940 km^2 in area, with a multi-use buffer of approximately 1005 km^2. Mixed deciduous forests and grasslands form the typical vegetation and support populations of tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sambar (*Cervus unicolor*), chital (*Cervus axis*), barasingha (*Cervus duvaucelii*) and gaur (*Bos gaurus*) (DeFries et al., 2010). KNP is the only habitat for the endemic hard hoofed subspecies of barasingha (translocation to other protected areas with suitable habitats began in 2015) (C. P. Singh et al., 2015). Additionally, KNP is central to tiger conservation in the region, and globally, as a crucial habitat for genetic connectivity between tiger populations (Dutta et al., 2015). Large mammal populations (of prey species and predators) inhabiting the central Indian forests use forest corridors and move between protected areas, including KNP, Pench NP, and Achanakmar NP (Fig. 1). Most of these corridors persist in topographically higher reaches of the

region, with underlying rocky soil. Human populations surrounding KNP are primarily rural poor.

Human population densities range between 182–195/km^2, and livestock densities range between 65–79/km^2 in the districts adjoining park boundaries (DeFries et al., 2010). Most households are agrarian and largely rely on local weekly markets for fresh produce. Agrarian households in this landscape are heavily dependent on the monsoon season as their main growing season and most irrigation is rain fed. Some households also harvest a second crop in winter months, usually wheat, after harvesting the monsoon paddy crop. There are seasonal differences in livelihood strategies that are likely to affect all aspects of rural living including food security. Summers are hot and dry, monsoons are largely responsible for the annual precipitation with winters being cool and dry. Human livelihoods around the protected area also rely on seasonal goods, including a heavy year-round reliance on forests for fuelwood (nearly 100% in this area compared to the 77% national average) and cattle grazing (WWF-India, 2014). Additionally, the central Indian region's human population includes a high density (>25%) of historically disadvantaged indigenous "scheduled tribes" or *adivasis* (Mohindra & Labonté, 2010). The "scheduled tribes" are formally recognized by the Indian government and predominantly reside in central and north-eastern India (Revankar, 1971). Finally, across India, small towns are increasing urbanization of rural populations, which might affect household food security (Gibson, Datt, Murgai, & Ravallion, 2017). The KNP landscape brings together international conservation goals (tiger conservation) and some of the highest densities of agrarian rural tribal populations in India (Lele, Ramanujam, & Rai, 2015).

From 2009 to 2013, the KNP management provided financial compensations to approximately 850 households who resettled out of the park into the villages around KNP. Approximately half the surveyed households in this study were resettled from KNP. Field teams conducted semi-structured interviews in three seasons (summer, monsoon, and winter) in 2016 and we previously used the data collected to compare between resettled and non-resettled neighbors in the landscape (Chapter 1 - Neelakantan et al. 2017). However, because we find that both livelihoods and food consumption patterns are similar in resettled and non-resettled households, we use our survey data in this analysis to explore influences of natural, social, and financial capital on food access (Neelakantan et al., 2017). We define our study site as the geographic region around KNP that includes the *tehsils* (sub-district administrative units) where we conducted surveys.

Survey data

Sampling design - We surveyed approximately 883 households around KNP (451 resettled households from Kanha NP and approximately 432 non-resettled neighboring households). We carried out surveys in three seasons to capture seasonal changes of food security and livelihoods in summer, monsoon, and winter (May 2016 – January 2017). We conducted semi-structured interviews, at each survey household, to collect data on socio-economic status, food access measurements, and interactions with forests. We used household location to measure distances to built-up areas (defined as areas containing a concentration of building and other structures, see – ISCGM, 2007a) and the core of KNP (strict protection areas within the larger administrative buffer). We compared our surveyed households to the local population across the entire study site to determine whether the households were representative of the population in terms of

distances from protected areas and towns (in our study built-up areas, ISCGM, 2007a) (Appendix 2).

Food security surveys - Our surveys included market checklists to assess whether all households had similar physical availability of foods from weekly fresh produce village markets (Chapter 1 - Neelakantan et al. 2017). Our primary survey instrument to measure the contributions of natural, social, and financial capital to food security was a semi-structured interview at each household repeated in each survey season (summer, monsoon, and winter). Our semi-structured interviews recorded responses from household heads and women of the household about their livelihoods and information on household members. We also asked about village markets accessed, belonging to a recognized scheduled tribe or caste, resettlement status, perception of land quality, perception of crop raiding by wild animals, and attacks on livestock and humans by large carnivores (Chapter 1 - Neelakantan et al. 2017). Finally, we recorded responses to standard queries to calculate household food access as described below.

Metrics to quantify food security - We use validated standardized multi-dimensional metrics measured at the household level with a 7-day recall time-period to assess food security in the KNP landscape (Jones et al., 2013). Of the four pillars of food security – availability, access, utilization and stability, we focus our analyses on food access in this study. To ensure our results were not influenced by geographic changes in food availability, we collected data on village markets and found that villages have similar physical availability of foods across the region (Chapter 1 - Neelakantan et al. 2017). In this analysis, we use household Food Consumption

Scores (FCSs) and Coping Strategy Indices (CSIs) in every survey season (summer, monsoon, and winter) (Table 1). The FCSs are weighted scores that weigh nutrition dense foods higher than low nutrition foods (usually staples) and scores are computed by weighted sums of foods as per their frequency of days consumed in the seven days (World Food Programme, 2008). We also computed the Coping Strategies Index (CSI) for each household in each survey season. Like FCSs, CSIs are weighted scores of frequency of days when a household reports certain behaviors. Behaviors included in the CSI are standardized and indicate food scarcity at the household, for example limiting meals by adults or non-working members of the household (D. G. Maxwell & Caldwell, 2008). For the purposes of our analyses, we extracted the frequencies of behaviors that signified using social capital to cope with food scarcity – specifically two behaviors: sending household members elsewhere to eat; and acquiring foods on credit or in lieu of work.

Data analysis

Analysis to compare FCS across seasons - We used an ANOVA and Tukey's post hoc test to compare mean household FCSs across seasons to identify significant seasonal differences. The FCS manual suggests standardized cut-offs to score household FCSs as households with poor, borderline, or acceptable food access (World Food Programme, 2008). Additionally, the standard score cut-offs are increased when diets include regular oil and sugar intakes to adequately account for inflated FCSs from these nutritionally poor food groups. In our study we use the standardized higher cut-offs (poor < 28, borderline > 28 < 42, and acceptable > 42) as households regularly use sugar in snacks as well as in daily intake of tea, and use oil for cooking.

Models to test contributions of financial, social and natural capital to food security - We ran mixed effects models (package lmer in R) to understand what livelihood factors of natural, social and financial capital from household surveys were significantly associated with household FCSs in our study (Fig. 2). We ran separate models for each season to explore if associations between livelihood factors and FCSs changed seasonally. To test robustness of results, in addition to mixed effects models we also conducted regression tree analyses (using ctree function from package party in R) to explore hierarchical subsets between modelled variables and food security. For example, regression trees can parse our data into subsets hierarchically to explore if assets (financial capital) or 'work in lieu of food' (social capital) are the most important differentiators in a given season between household FCSs, followed by different sources of income (financial capital). We separately ran regression tree analyses for each season in our data.

Variables used in models - We measured natural capital indicators as effort spent in *tendu* trade, distance from KNP, and tree cover available per capita. We also measured direct reliance on forest foods (foraging and hunting) and firewood at each household. Finally, we recorded forest reliance in terms of cultural, medicinal and any other importance at each household. Our data on cultural, direct food consumption and firewood were similar for resettled and non-resettled household with a year-round unanimous reliance on forests for firewood and grazing, but sparse direct reliance on forests in all other responses. We measured the hours spent on *tendu* trade in summer per household that reported *tendu* trade effort (Appendix 2). We include distance from KNP as a proxy measure of gains from protected natural capital that we could not directly measure. We also estimated tree cover within various use radii (1 km, 2 kms, 4 kms, 6 kms and 8 kms) as a proxy for unmeasured natural capital gains from forests that contribute to household

food security. Our tree cover estimate includes non-protected forests that households use outside of KNP. Various studies have found gains to food security through access to forests that our surveys could not directly capture, especially bush-meat, agricultural production stability, ground water recharge, and water filtration (Bharucha & Pretty, 2010; Costanza et al., 1997; Golden et al., 2011; Johnson et al., 2013; Zhang et al., 2007). We used multiple radii of forest use based on previously estimated use radii by households for grazing cattle in the KNP landscape (Agarwala, 2014) and divide these estimates by the number of households at a village to get a per household measure of available forest.

We measured social capital as responses to two queries on the CSI questionnaire. We specifically wanted to know if social capital increases are associated with higher food security and therefore we split the combined responses to the CSI into their individual components (frequencies of days the coping strategy is used in the past seven days and weight according to severity of behavior). We only included the coping strategies that directly indicated use of a household's existing social capital – sending household members to eat elsewhere and accessing foods on credit or in lieu of work (Appendix 2). Moreover, we did not use the weights but only used the reported frequencies in our analyses as we were not combining these scores.

We used household asset indices, distances to built-up areas, and sources of income as our indicators of financial capital. We measured financial capital by responses on the semi-structured interviews about household assets to calculate a weighted asset index using assets listed on the Indian government household census with higher weights for the least prevalent and high economic assets (Kishor & Parasuraman, 1998). We also recorded categorical information on

sources of income at the household level (agriculture, labor, salaried jobs). We caution readers to not interpret our income profiles as those from single sources (agriculture or labor or salaries or *tendu*), they instead follow a logical but context dependent profiling. Labor, salaried jobs and *tendu* income households reported labor incomes, salaries or *tendu* trade incomes (respectively) as at least one income source. Households with agricultural incomes but no labor or salaries were classified as agricultural households. In addition to household level measurements of financial capital, we included distance to built-up areas in our models to understand if proximity to more economic hubs afforded financial capital to households that remained unmeasured in our surveys (Appendix 2) (ISCGM, 2007).

We used mixed effects models to control for variables that could affect household FCS (Appendix 2). We included random effects in our models to capture variability not captured in fixed effects related to *tehsil* (administrative block), whether a household was resettled or not, within the buffer or not, and scheduled tribe or not. We also included if the village had a tarred road ("*pukka*"), kitchen garden diversity (supplement source to market bought produce), and household dependency ratio. In our study, we used the number of children at the household divided by adults at the household as a dependency ratio because it is very common for adults to contribute to the household incomes by working in the fields or other jobs well into their old age. In mixed models and regression trees, we standardized all continuous variables, except response variables, and checked for collinearity (for correlation matrix see – Appendix 2).

Results

Seasonal and spatial patterns of food security

Overall, our surveys show that the food security of the vast majority of households is below acceptable levels in the KNP landscape. More than 80% report poor or borderline FCSs year-round (Fig. 3). In monsoon, more households report poor FCSs (n = 248) and fewer households report borderline or acceptable FCSs (n = 491 and n = 144) than in summer and winter (194 and 179 reporting poor, 520 and 517 reporting borderline and 169 and 187 reporting acceptable for summer and winter respectively). We found that FCSs were significantly different across seasons ($F(2, 2646) = 11.29$, $p<0.001$). Additionally, the significant seasonal differences are mainly due to lower mean monsoon FCS compared to summer and winter ($p<0.001$). Mean FCSs are not significantly different when we compare summer and winter. We also found no clear geographic patterns in household FCSs across the KNP landscape. We found that FCSs did not vary with distance from built up area (proxy for unmeasured associations with financial capital), and the KNP perimeter (proxy for unmeasured gains from protected natural capital) (Appendix 2). However, to explore if proximity to KNP or built-up areas interacted with other livelihood aspects we continued to include these variables in our analyses. We found that predominantly households report incomes from agriculture, labor, and salaried jobs (Appendix 2). Incomes from *tendu* trade are reported only by a few households (n = 3), but the number of households involved in collection when asked about days spent collecting *tendu* are a more accurate measurement of this trade.

Model results

Financial capital - We found that household income sources from off-farm salaried employment is positively associated with FCSs in summer and with household asset index across seasons (Table 2 and 3). Additionally, asset indices are positively associated with FCSs across all seasons. Labor incomes are positively associated with FCSs in summer but negatively associated with FCSs in monsoon and winter. Proximity to built-up areas (proxy for unmeasured associations with financial capital) is positively associated with asset indices of households year round. Clearly, there is a positive association between salaried incomes and assets with FCSs in the KNP landscape (Table 3).

Natural capital - Tree cover estimated within a use radius of two kilometers is also positively associated with FCSs in monsoon and with assets through summer as well as monsoon across all use radii (1 km, 2 kms, 4 kms, 6 kms and 8 kms). Finally, as expected, *tendu* effort (defined as man-hours per household spent in *tendu* collection in summer) is positively associated with FCSs in summer. While access to forests is positively associated with assets, the households further away from KNP report higher assets (Table 3).

Social capital - "Food in lieu of work or credit" is negatively associated with FCSs in summer and household asset indices in summer as well as in monsoon. However, the same coping behavior of accessing "food in lieu of work or credit" is positively associated with household FCSs in monsoon and both FCSs as well as assets in winter (Table 2 and 3). Sending household members to eat elsewhere is not significantly associated with FCSs or asset indices in our study.

Control variables - Higher home garden diversity is positively associated with FCSs (winter) and household asset indices (summer and winter) (Table 2 and 3). Households with more mouths to feed (higher dependency ratio) are negatively associated with household asset indices in summer and monsoon (Table 3).

Regression tree results

We also find that financial capital indicators (assets and sources of income) partitioned our household data in summer (Appendix 2). Households with highest assets (n = 94) formed a distinct group as did households with the poorest asset indices (n = 334). The remaining households split into two groups according to their sources of income – one group with agricultural or labor incomes (n = 435) and the second group included households with salaried incomes or *tendu* incomes (n = 20).

In monsoon, the households with lowest asset indices separate out from all other households (n = 299) as did those with the highest and second highest asset indices (n = 110 and n = 36 respectively) (Appendix 2). All other households partition into subsets by those with higher social capital (n = 118) and then by sources of income. Households with lower social capital and labor incomes form a distinct subset (n = 320) and the households with highest and second highest FCSs all have incomes that were either agricultural or from salaries.

Finally, in winter, households, with labor incomes and kitchen gardens separate out from those with social capital, agricultural incomes, and salaries (Appendix 2). Households with labor incomes further partition by higher garden diversity (n = 263) and lower garden diversity (n = 312). Households with agricultural and salaried incomes with higher asset indices partition into a distinct group (n = 50). Households with agricultural and salaried incomes with lower asset indices partition according to social capital – those with higher social capital (n = 30) and those with lower social capital (n = 228).

Regression tree results reinforce the results from mixed effect models highlighting the importance of financial capital in association with higher FCSs in the KNP landscape. Across seasons, income sources and assets are most highly associated with FCSs. The regression trees also highlight the role of "food on credit or in lieu for work" in monsoon and winter. Across all survey seasons, natural capital indicators do not partition our data in regression trees. A key feature of rural livelihoods linked to food consumed, household kitchen garden diversity partitions our data in winter.

Discussion and conclusions

Results indicate that FCSs (food access metric) are borderline or poor for more than 80% of households. Our results suggest that households have varying financial access to foods from uniformly available market foods in the KNP landscape. The worsening of food consumption scores (FCS) in monsoon season could be due to multiple reasons, including decreasing financial capital due to fewer options for off-farm incomes (off-season for construction labor, *tendu* leaf

collection and ecotourism) coupled with increased pace and extent of agricultural work during main cropping season. Worsening FCSs in monsoon also indicate times of stress with our reported withdrawals from household social capital as 'food on credit or in lieu of work' in farming seasons. While there exists a strong seasonal trend in household FCSs around KNP, there is no clear spatial pattern to FCSs across seasons with households (Appendix 2). In our study, households close to or further away from built-up areas (unmeasured associations with financial capital) or the KNP perimeter (unmeasured associations with natural capital) have both high and low FCSs. However, there is a positive association between being further away from KNP and household assets in monsoon. The positive association between assets and distance from KNP may be due to multiple reasons – for example, households further away from KNP might have more steady incomes without the impacts of KNP related tourism off-season. Our findings suggest that proximity to economic opportunities affects financial capital of a household which in turn affects FCSs.

The importance of steady incomes is further highlighted, in our study, by the positive associations between salaried jobs and household FCSs in summer as well as economic access to market foods year-round. Also, as we expected, proximity to built-up areas is associated with higher asset indices (increased financial capital) all year-round as urban centers in the KNP landscape might provide more income avenues. Incomes from labor in our study encompass a broad category and are the second most common kind of income after agricultural incomes. We include differing kinds of labor wages under the labor incomes category – daily labor wages that are largely an indication of desperation for additional incomes, seasonal labor remittances from urban centers that might have more longevity in rural households around KNP, and agricultural

labor incomes that are especially common in monsoon. A possible explanation of the seasonal association of labor incomes with FCSs in the KNP landscape relates to the seasonality of certain types of labor incomes such as monsoon agricultural labor and summer off-farm labor.

Labor incomes in summer are unlikely to be on-farm labor as there are largely fallow fields in this season and therefore they are more likely to be daily wage labor. We explain the positive association between labor incomes and FCSs in summer as it is an additional income in a non-agricultural season of the year, especially useful for households with few assets and no other income opportunities. In monsoon and winter, households with very low asset indices that report labor incomes have some of the lowest FCSs. Seasonal labor remittances are likely to play a role on household FCSs year-round, but there are large migrations in monsoon, suggesting remittances might be concentrated starting in monsoon each year and continue through winter. Agricultural labor is most prevalent in monsoon but could also be used for double cropped fields in winter. Our findings also suggest, that households use labor incomes within the same season (no significant association with assets across all survey seasons), despite of our broad description of labor incomes pooled under one category. Considering that most households report agricultural and labor incomes, we expected poor households (low assets and no salaried incomes) to use opportunities for additional incomes from access to natural capital and social capital coping strategies to compensate in times of household stress and food scarcity.

Natural capital is only marginally associated with food security – an important consideration for the largely poor to borderline FCS households in the KNP landscape. *Tendu* trade is an important

part of human and forest dynamics in the central Indian region and KNP landscape. *Tendu* trade allows poorer households with fewer assets to attain higher FCSs in summer with incomes from NTFP collection. At present, there are few studies on the *tendu* trade in central India and quantitative data on *tendu* trade can allow for greater understanding of its influence on household FCSs. An additional important impact of studying *tendu* trade could be more transparent monetary transfers (Lele et al., 2015). Finally, we were not able to explore mechanistic gains from forest available to households and their food security but significant positive associations between per capita forest availability (unmeasured natural capital) and FCSs in monsoon suggest households might rely on forests in times of food scarcity. Household assets are also positively associated with forest access in monsoon and winter but not with proximity to KNP, suggesting that non-protected forests play a role in allowing households to accrue more assets by converting natural capital to financial capital. Regression tree analyses suggest that variables related to financial capital are the main differentiators of variances in household FCSs, not tree cover in any use radii or effort in *tendu* trade. We reiterate that data were collected on all livelihood aspects where forests might play a role – financially, culturally and direct consumption of any kinds of forest goods. Households rely on forests for firewood and grazing cattle all year-round but reports of other direct uses of forests are rare in our surveys across seasons.

Finally, "food for work or on credit" is most useful in seasons with agricultural work. Monsoon and winter have many opportunities for on-farm work for food that suggest avenues for social capital to be useful. We suggest the negative association of 'food for work or on credit' as a measure of social capital with FCSs in summer is due to non-farm related foods for work or on credit. For example, during summer, 'food for work' could involve unpaid local labor

opportunities and credit seeking would be a true indicator of food scarcity. Assets and social capital are positively associated only in winter, confirming these patterns for labor (paid and unpaid) arising in seasons with on-farm activity (here – winter). The negative association of 'food for work' and 'food on credit' and asset indices in monsoon suggest that while the coping strategy provides food in monsoon (positive association with FCSs) it is an indicator of poorer (low asset index) households trying to cope in times of food scarcity.

We strongly suggest winter kitchen gardens as an avenue for food insecurity alleviation in the KNP landscape. Kitchen gardens are also positively associated with assets in summer and might have the potential to increase food groups consumed by indirectly increasing assets (minimizing food expenses). We included kitchen gardens as a control variable with direct mechanistic links to household FCSs by providing a low cost and low effort supplementary stock of fresh produce. Kitchen gardens associated with higher FCSs are a non-commercial outcome of human capital. Additionally, among our measurements there remain overlaps between acquiring financial capital and human capital (education, skills to gain employment or farming know how).

Our study sheds light on the contribution of different types of capital (financial, social, and natural) on household FCSs around KNP but has several limitations. We acknowledge that human well-being includes subjective, qualitative aspects (mental well-being, perceptions of contentment, security, and happiness among others) that are not included in our study and we limit our findings to the food access of households around KNP (Leisher, Samberg, van Buekering, & Sanjayan, 2013). Additionally, while we address how natural, social, and financial

capital indicators that we measured can affect food security in the KNP landscape we recognize that indicators of agency or power structures in the landscape have not been included in these analyses (Kumar, 2002; Lele et al., 2015). Similarly, we tested if the indicators chosen by us for financial, social and natural capital were associated with food consumption scores. Our indicators are specific to livelihoods in the KNP landscape and may differ in other landscapes. Finally, data on non-timber forest products in our study were limited to responses to survey queries.

In terms of interventions to improve food security in the KNP region, increased financial capital through salaried incomes in the KNP landscape would be significantly positively associated with household FCSs. Small businesses, vocational opportunities, and cottage industries are likely to provide steady incomes that are better than unstable or desperate incomes, for example labor or unpaid “food for work”. An avenue to alleviate food insecurity could be to create additional employment during monsoon. Households already show patterns of using urban avenues to increase incomes and accrue assets in the landscape; therefore, incentives to explore other rural incomes during monsoon season could improve food security in the landscape. Our results also suggest that promotion of kitchen gardens could alleviate food insecurity in the KNP landscape. Kitchen gardens are not very costly to maintain and can provide supplementary higher nutrition by fresh foods year-round in addition to market bought foods.

While we recognize that creating new job opportunities involves economic growth and policies far beyond the mandate of managers in the study region, our results suggest that interventions

leading to more salaried jobs are likely to be the most positively associated with steady increases in household FCSs. We stress that in the current vacuum of more regular incomes from jobs, household food access has significant positive associations with natural (non-protected forests access and *tendu*) and social capital ("food for work" or "food on credit").

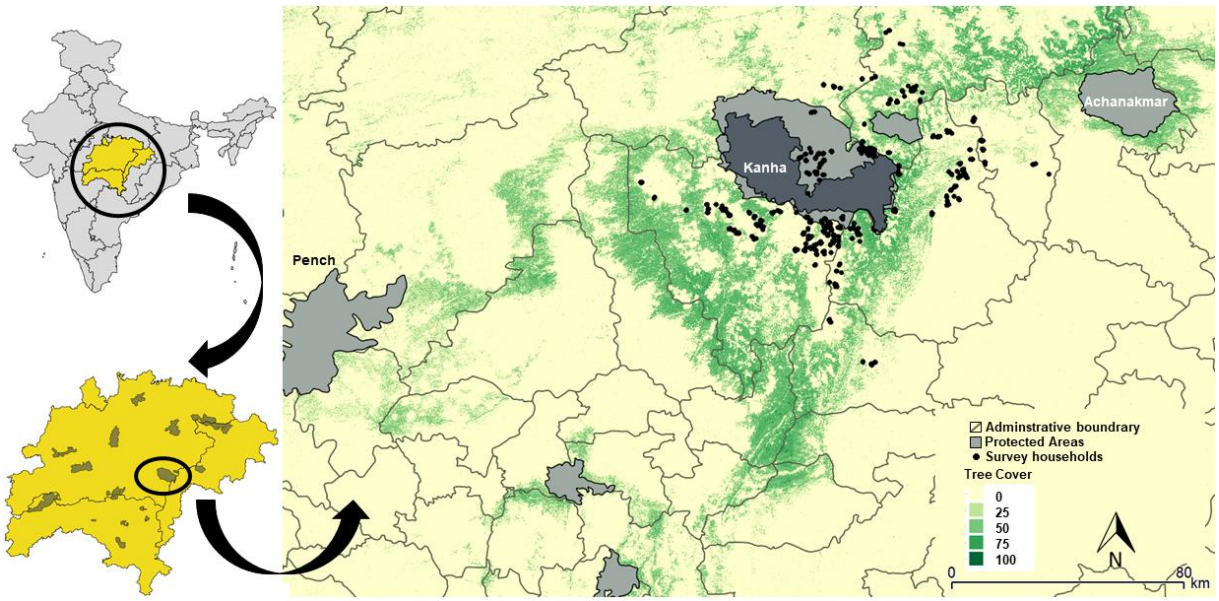
The dominating influence in our measured indicators of financial capital relative to natural and social capital to household food security around KNP is in contrast to many studies around the world that report direct benefits from natural capital for well-being of people around protected areas (Bharucha & Pretty, 2010; Golden et al., 2011; Sunderlin et al., 2005). We suggest that more studies recognize that increasingly in landscapes where populations are less directly reliant on protected areas (for goods and services), people are likely to depend on financial capital to meet most of their well-being needs (Asih & Klasen, 2017; Thulstrup, 2015). Protected areas are less likely to be directly important for household food access in landscapes where people are able to or prefer to substitute wild foods for market goods and agricultural production is commercial. Agricultural practice that is reliant on external inputs compared to many recognized ecosystem services tied to forest quality (for example – pollinator services) also diminishes the direct links between forests and agricultural yields. Rural livelihoods centered on market driven wealth generation are likely to urbanize and therefore unlikely to move towards a more subsistence lifestyle with heavy reliance on natural capital (Wunder et al., 2014).

Acknowledgements

We greatly value and appreciate the support and openness of the Madhya Pradesh Forest Department, especially officials who manage Kanha National Park. We are also grateful for the National Tiger Conservation Authority and our colleagues at Wildlife Institute of India to be able to work in the buffer zone villages around Kanha National Park. We are deeply grateful to the respondents of our surveys to spare their valuable time repeatedly to provide data for our research. We also thank our survey team for their dedicated data collection even in tough field conditions during monsoons. We conducted our study under the IRB protocol number AAAN5603, exemption subsection 45CFR46.

Figures and Tables

(a)



(b)

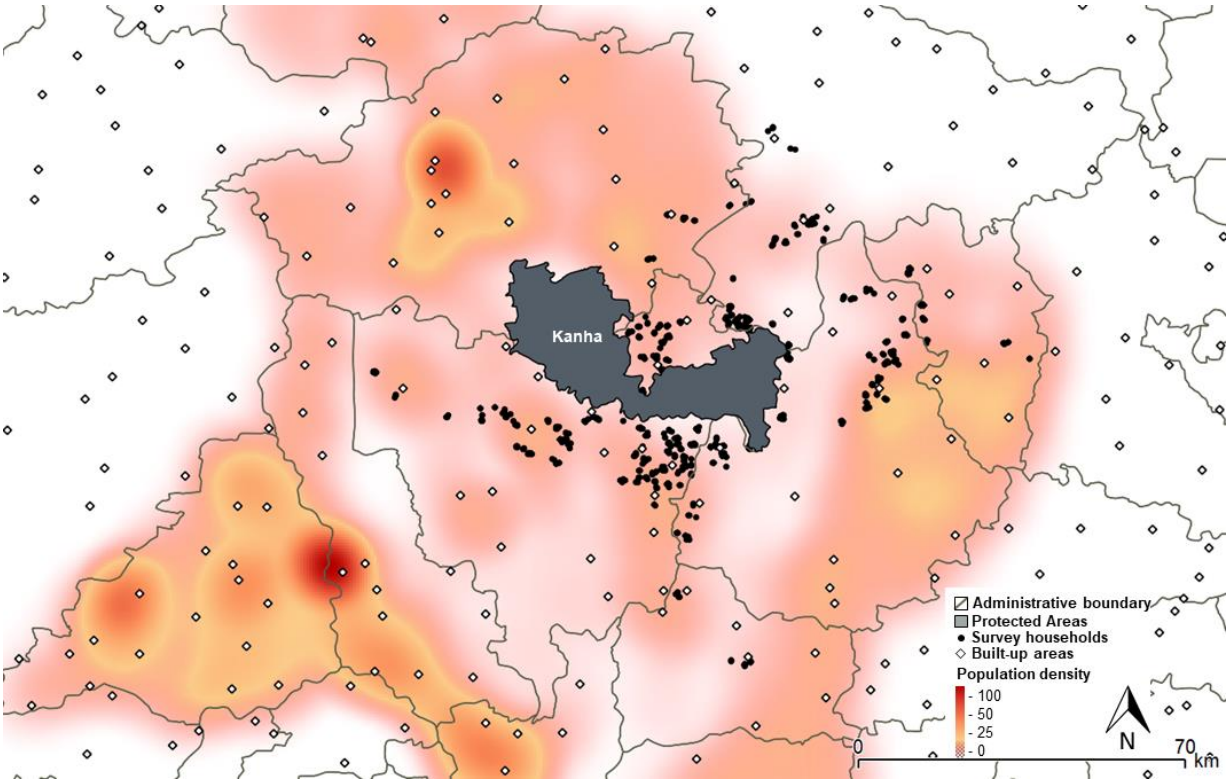


Figure 1: Study site with corridors between protected areas within human-dominated landscape and resettlement locations.

(a) Inset maps show location of study site in the central Indian landscape and tree cover percent (yellow to green background) that include non-protected wildlife corridors across the landscape (M. C. C. Hansen et al., 2013). KNP strictly protected core area in dark grey. (b) Heat map of the number of households at each census village and town (Maximum number of households is 15503) within study *tehsils* (administrative units) and built-up areas in the KNP landscape (Census of India, 2011; ISCGM, 2007a). Black dots signify survey locations.

Table 1: Metrics of food access used in study.

Our study focuses on household access in our analyses using Food Consumption Scores (FCSs) and Coping Strategies Indices (CSIs) that are weighted scores of consumed food groups and behaviors in times of food scarcity respectively.

Metric Name	What it measures	Recall duration	Range of Values	References
Food Consumption Score (FCS)	Frequency of 9 food groups consumed * weight	7 days	0 to 112	(World Food Programme, 2008)
Coping Strategies Index (CSI)	Frequency of 12 behaviors * weight	7 days	0 to 203	(D. G. Maxwell & Caldwell, 2008)

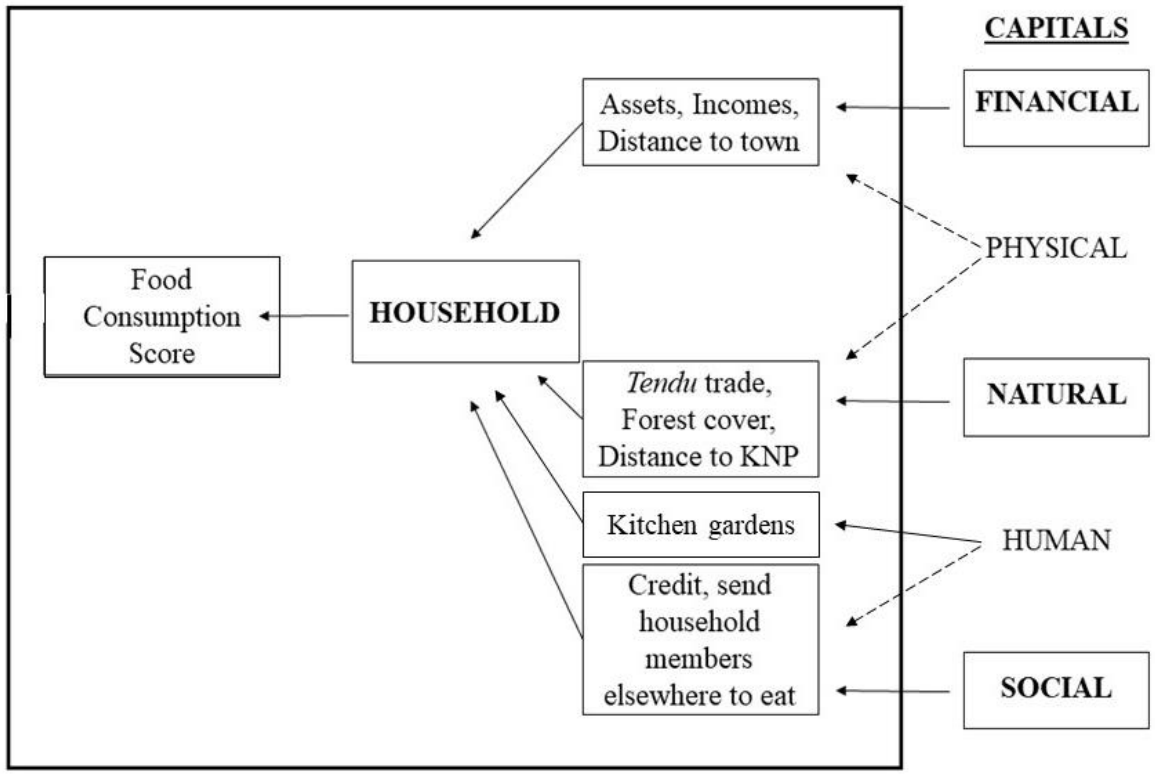


Figure 2: Conceptual diagram of links between food security, study measurements and five capitals model of sustainable development.

Conceptual diagram showing links between our measured livelihood factors, food consumption scores, and the five capitals model of sustainable development. Direct links indicated by solid arrows and indirect links to measured factors indicated by dashed arrows.

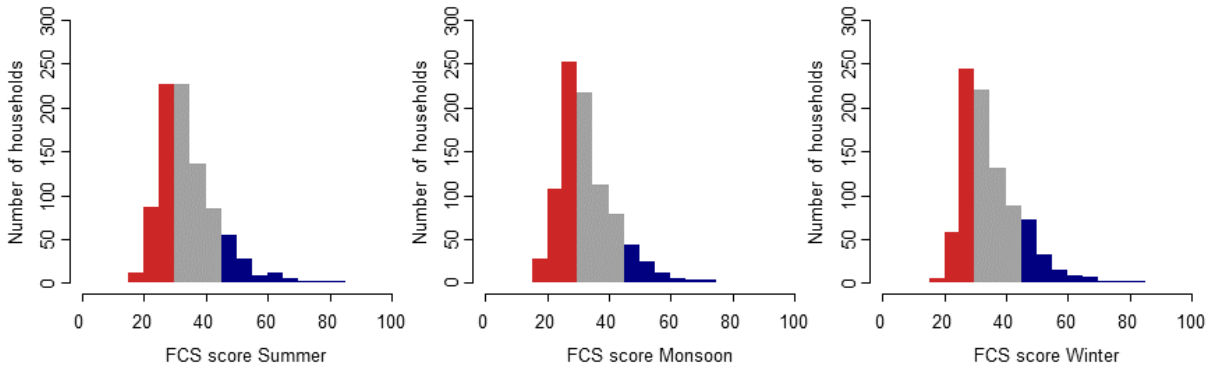


Figure 3: FCSs across seasons in surveyed households.

Surveyed households that report poor (red, FCSs < 28), borderline (grey, FCSs >= 28 and <42) and acceptable (navy, FCSs =>42) FCSs across seasons in the KNP landscape. Monsoon has the highest number of households with poor FCSs (n = 248) and the lowest number of households reporting borderline (n = 491) as well as acceptable (n = 144) scores.

Table 2: Livelihood factors associated with household FCSs in each survey season categorized as natural, social, and financial capital.

Significance of predictors= around 0.05 '.' / <0.05 * / <0.01 ** / <0.001 *** FCS response, SD = Standard Deviation, n = 883, *tehsil* = 11, scheduled tribe = 4; resettled = 2; buffer = 2						
	FCS SUMMER		**FCS MONSOON**		**FCS WINTER**	
Financial Capital Indicators	Estimate	SD	Estimate	SD	Estimate	SD
Jobs - salaried	6.18 ***	1.58				
Jobs - labor	1.77 **	0.67	-2.46 ***	0.66	-4.84 ***	0.66
Assets	2.07 ***	0.32	1.63 ***	0.30	1.58 ***	0.31
Distance to town						
Pukka road at village						
Natural Capital Indicators						
Forest per household in village (1/2/4/6/8 kms radius)			0.54 (2 kms) '.'	0.31		
Distance to KNP core perimeter						
Tendu effort	0.73 *	0.30				
Jobs – *Tendu*						
Social Capital Indicators						
Eat Elsewhere						
Food for work / on credit	-1.02 **	0.31	1.22 ***	0.31	1.12 ***	0.31
Control Variables						
Garden diversity					1.37 ***	0.30
Dependency ratio (Children/Adults)						
Conditional R sq	0.12		0.09		0.14	
Marginal R sq	0.10		0.08		0.13	

Table 3: Livelihood factors associated with household asset index in each survey season categorized as natural, social, and financial capital.

Significance of predictors= around 0.05 '.' / <0.05 * / <0.01 ** / <0.001 *** ASSETS response, SD = Standard Deviation, n = 883, *tehsil* = 11, scheduled tribe = 4; resettled = 2; buffer = 2						
	ASSETS SUMMER		**ASSETS MONSOON**		**ASSETS WINTER**	
Financial Capital Indicators	Estimate	SD	Estimate	SD	Estimate	SD
Jobs - salaried	4.77 ***	0.66	5.07 ***	0.97	5.96 ***	0.86
Jobs - labor						
Distance to town	-0.32 *	0.13	-0.39 *	0.16	-0.43 **	0.16
Pukka road at village						
Natural Capital Indicators						
Forest per household in village (1/2/4/6/8 kms radius)	0.34 – 0.27 * (2/4/6/8 kms)	0.14 / 0.13	0.44 ** (2/4/6/8 kms)	0.16		
Distance to KNP core perimeter			0.36 *	0.16	0.48 **	0.16
Tendu effort						
Jobs – *Tendu*						
Social Capital Indicators						
Eat Elsewhere						
Food for work / on credit	-0.27 *	0.13	-0.38 *	0.16	0.31 '.'	0.16
Control Variables						
Garden diversity	0.47 ***	0.13			0.60 ***	0.16
Dependency ratio (Children/Adults)	-0.25 '.'	0.13	-0.4 *	0.15		
Conditional R sq	0.11		0.08		0.09	
Marginal R sq	0.10		0.07		0.07	

CHAPTER 4 - IMPACTS OF HUMAN RESETTLEMENT FROM PROTECTED AREAS ON LANDSCAPE LEVEL CONSERVATION OF WILDLIFE: A CASE STUDY FROM CENTRAL INDIA.

Amrita Neelakantan, Ruth DeFries, and Ramesh Krishnamurthy

Abstract

Since the origin of the protected area network, authorities have resettled people in the interest of wildlife conservation. However, the impacts of resettlement on wildlife corridors connecting increasingly insular protected areas and the interaction of resettlement with existing human-wildlife conflict (HWC) outside of protected areas remains unclear. Using Kanha National Park (KNP) in central India as a case study, we quantified impacts of 450 resettled households (>90% of all resettled households from 2009 to 2013) on non-protected forests at their new settlement locations. We measured forest use for cattle grazing, *tendu* leaf extraction (a commercial non-timber forest product) and consumption of forest foods. We also quantified HWC risks that resettled households face at their new settlement locations. Overall, most resettled households (330) have moved to existing villages that lie outside of wildlife corridors around KNP. They comprise less than ten percent of existing populations at most of their new settlement villages. Many resettled households and their non-resettled neighbors face high HWC risks due to the spatial patterns of HWC around KNP. Controlling for assets and proximity to forest, resettled households own more cattle, are less involved in *tendu* trade, and consume fewer forests foods than non-resettled neighbors. Model results suggest that increasing off-farm economic opportunities would reduce pressures on forest resources for both resettled and non-resettled households. Our findings, while limited to the KNP landscape, provide approaches applicable in other human-dominated places to design resettlement strategies towards landscape-level conservation goals.

Introduction

The global protected area network covers more than 12 percent of the earth's terrestrial surface, a large part of which are inviolate wildlife areas formed by the dispossession or resettlement of human communities (Brooks et al., 2004; West et al., 2006). Resettlement of people from protected areas continues to be an important conservation strategy in many countries facing acute land competition (Cernea & Schmidt-Soltau, 2006; Harihar et al., 2014; Karanth, 2007). Resettlement from protected areas as a successful conservation strategy is most clear in the case of charismatic megafauna where the removal of human communities has relieved habitats from disturbance and alleviated within park human-wildlife conflict (HWC) (Harihar, Pandav, & Goyal, 2008; Lamichhane et al., 2017; H. S. Singh & Gibson, 2011).

However, human pressures from communities within protected areas are only one aspect of anthropogenic effects on endangered wildlife at a landscape scale. Multiple threats such as encroachment of habitats from external actors, poaching, unsustainable extraction of forest resources and the degradation of connectivity between protected areas detrimentally affect vulnerable species populations (Karanth & DeFries, 2010; Mainka & Trivedi, 2002; Peres et al., 2010). Human use of non-protected wildlife corridors often severe connectivity between protected areas and consequently threaten endangered species survival (DeFries et al., 2007; Pressey et al., 2007; Tscharntke et al., 2012). With the breakdown of dispersal, many endangered species face threats from genetic inbreeding and are not able to maintain minimum viable populations in the wild (Dutta et al., 2013; Natesh et al., 2017). In response, wildlife corridors have been identified to maintain connectivity between protected areas, for example - the Yellowstone to Yukon Conversation initiative (Chester, 2015), and the extensive analyses for

tiger corridors across India (Dutta et al., 2015; Maldonado et al., 2013; Thatte et al., 2018; Yumnam et al., 2014). Within the landscape context of conservation, resettlement of people from within protected areas potentially affects the efficacy of landscape-level conservation, connectivity between protected areas and specific habitat configuration that facilitates meta-population structure. Whether resettlement truly alleviates pressures on wildlife or merely shifts them to crucial but unprotected corridors is an open question.

Successful conservation aligns people's goals with conservation goals, including access to adequate resources in their new settlement locations (P. J. Ferraro, Hanauer, & Sims, 2011; Karanth, 2007; Naughton-Treves et al., 2005). In many conservation landscapes, protected natural resources and unprotected resources (around KNP – unprotected wildlife corridors) together provide ecosystem services and goods critical for the long-term well-being of human populations (Ruth DeFries et al., 2010; A. J. Hansen & Defries, 2007). The role of maintaining unprotected habitats for sustainable human use is an additional motivation to understand resettlement impacts on non-protected natural resources at new settlement locations.

An important consideration in aligning well-being of local populations with conservation is the management of HWC around protected areas (Barua et al., 2013; Miller, Jhala, & Schmitz, 2016). Many megafauna affect people and their livelihoods detrimentally through attacks on humans and livestock as well as economic losses through loss of crops (Harihar et al., 2015; Karanth, Naughton-Treves, Defries, & Gopalaswamy, 2013). Additionally, HWC is not restricted to areas with suitable habitats for residing populations or stepping stone islands of suitable habitats between protected areas - many animals use habitats differently during mating

or dispersal than when residing in an area (Keeley, Beier, Keeley, & Fagan, 2017; Krishnamurthy et al., 2016; Sarkar, Krishnamurthy, Johnson, Sen, & Saha, 2017). HWC levels in the Kanha National Park (KNP) landscape mirror the reality that dispersing tigers often encounter humans when attempting to cross human-dominated landscapes (Karanth et al., 2012). Undirected resettlement of households out of protected areas into human-dominated landscapes might result in increased households in high-risk HWC zones as well as increased HWC risks due to higher human activity in areas used by resident and dispersing wildlife.

Conservation is increasingly aware of and includes the mitigation of social costs of protected area management, which is primarily borne by local vulnerable human communities (Cernea & Schmidt-Soltau, 2003). Resettlement as a conservation policy is especially contentious because it brings to fore the difficult reconciliations required to create inviolate habitats for wildlife without impinging on legal rights of human communities within protected areas (Kashwan, 2013; Sekar, 2016; Shahabuddin & Bhamidipati, 2014). Resettlement of people in the current environment of increased awareness of social consequences of conservation policy provides an opportunity to engage with human needs at new settlement locations. Studies suggest that without adequate understanding of forest use by local people, especially resettled households, human pressures on protected areas are likely to manifest at new settlement locations and degrade important connections between protected areas (DeFries et al., 2005; DeFries et al., 2007). However, the landscape view of conservation goals alongside social goals allows for dialogue and planning for human as well as wildlife needs (Ruth DeFries et al., 2010; Gardner et al., 2009; Maldonado et al., 2013; Mondal & Nagendra, 2011). In many studies, the poorest households are the most dependent on forest resources and increasing their well-being offers an opportunity to truly

alleviate human pressures on important areas for conservation – protected as well as not protected (Adams et al., 2004; Golden et al., 2015; Naughton-Treves et al., 2005; Reed, van Vianen, Foli, et al., 2017; Sunderlin et al., 2005).

Our study explores the impacts of resettlement on the corridors connecting Kanha National Park (KNP) to other protected areas in the central highlands in India. We assess if resettled households are clustering in conservation-relevant, relatively uninhabited areas. We then investigate if the current resettlement in the KNP landscape results in disproportionately more resettled households within previously identified human-wildlife conflict zones. Finally, we compare forest use between resettled households with their non-resettled neighbors at the new settlement villages and explore the livelihood factors that are significantly associated with forest use in the KNP landscape for resettled as well as non-resettled households.

Methods

Study Site

Kanha National Park (KNP) (22.3333° N, 80.6333° E), established in 1955, is one of India's most well-known Tiger Reserves. KNP is approximately 940 km^2 in area and includes an additional a multi-use buffer of approximately 1005 km^2. Mixed deciduous forests and grasslands form the typical vegetation and support populations of tiger (*Panthera tigris*), leopard (*Panthera pardus*), wild dog (*Cuon alpinus*), sambar (*Rusa unicolor*), chital (*Axis axis*), hard-ground barasingha (*Rucervus duvaucelii duvaucelii*) and gaur (*Bos gaurus*). KNP is the only habitat for the endemic hard-ground subspecies of barasingha (translocation to other protected areas with suitable habitats began in 2015) (C. P. Singh et al., 2015). Additionally, KNP is central to

tiger conservation in the region, and globally, as a crucial habitat for genetic connectivity between tiger populations (Dutta et al., 2015). Large mammal populations (of prey species and predators) inhabiting the central Indian forests use forest corridors and move between protected areas, including KNP, Pench NP and Achanakmar NP (Fig. 1). Most of these corridors persist in topographically higher reaches of the region. Human populations surrounding KNP are primarily rural poor.

Human population densities range between 182–195/km^2, and livestock densities range between 65–79/km^2 in the districts adjoining park boundaries (DeFries et al., 2010). Most households are agrarian and purchase food from local weekly markets as well as few gathered forest foods. Agrarian households in this landscape are heavily dependent on the monsoon season as their main growing season and most irrigation is rain fed. Some households also harvest a second crop in winter months, usually wheat, after harvesting the monsoon paddy crop. There are seasonal differences in livelihood strategies that are likely to affect all aspects of rural living including forest reliance. Human livelihoods around the protected area rely on seasonal forest goods (such as *tendu* leaf – a commercial non-timber forest product), including year-round reliance on forests for fuelwood (nearly 100% in this area compared to the 77% national average) and cattle grazing (WWF-India, 2014). Summers are hot and dry, monsoons are largely responsible for the annual precipitation with winters being cool and dry. Additionally, the central Indian region's human population includes a high density (>25%) of historically disadvantaged indigenous "scheduled tribes" or *adivasis* (Mohindra & Labonté, 2010). The "scheduled tribes" are formally recognized by the Indian government and predominantly reside in central and north-eastern India (Revankar, 1971).

Similar to many human-dominated landscapes with embedded protected areas, KNP managers provide compensations for HWC due to attacks on humans and livestock but households also incur losses due to crop damage by wildlife (Karanth et al., 2012; Miller, Jhala, Jena, & Schmitz, 2015; Miller et al., 2016). Compensations are more likely for attacks on humans and livestock than for crop damage, especially within the KNP administrative multi-use buffer (Karanth et al., 2012). However, animals stray outside of the management bounds of protected areas and innovative management of HWC is critical to mitigate these detrimental effects to living in close proximity to protected areas and wildlife (Krishnamurthy et al., 2016; Madhusudan, 2003). Finally, across India, small towns are increasing urbanization of rural populations that might affect household reliance on forest resources (Gibson et al., 2017). The KNP landscape brings together international conservation goals (tiger conservation) and some of the highest densities of agrarian rural tribal populations in India (Lele et al., 2015).

From 2009 to 2013, the KNP management provided financial compensations to approximately 850 households who resettled out of the park into the villages around KNP according to standardized policy by the National Tiger Conservation Authority (NTCA). The current policy is in contrast to historical evictions in the 1970s and 80s from KNP in that it is not directed to particular locations, provides standardized financial compensations, and households can move to areas in the landscape where they can procure land. The NTCA policy highlights changes in resettlement policy in response to criticisms of historical evictions from protected areas. We define the bounds of our study site as the geographic region around KNP that includes the *tehsils*

(sub-district administrative units) within which all surveyed villages and households are located (Fig. 1).

Survey Data

We surveyed approximately 451 resettled households from KNP and approximately 432 non-resettled neighboring households. We carried out surveys in three seasons to capture any seasonal changes of forest reliance, HWC and livelihoods in summer, monsoon and winter (May 2016 – January 2017). We conducted semi-structured interviews, at each survey household, to collect data on socio-economic status, food access measurements and interactions with forests. In total, we use data from 883 households across all three survey seasons. The KNP management provided data to locate all 850 of the resettled households at their new settlement locations across more than 143 villages across five districts of the two Indian states – Madhya Pradesh and Chhattisgarh. The drop in the number of resettled households (850 to 451) in our surveys is predominantly due to households merging when resettling outside of the park as well as a few households (<10%) that we could not locate through all three survey seasons. To sample non-resettled households, our field assistants used the established social science method of picking every seventh house in a random walk method using a coin toss to change directions (Chapter 1 - Neelakantan et al., 2017). We used the Indian government census for total number of households at villages within study *tehsils* in spatial analyses (Census of India, 2011).

Spatial Analyses

Spatial analyses of resettlement impacts on wildlife corridors use a previous study in the region on habitat connectivity (Dutta et al., 2015). We specifically use the resistance data on habitat

suitability for wildlife movement analyzed as current flow between protected areas as nodes, calculated as a unit-less weighted resistance measure using data from land cover / land use, transport infrastructure and population density in areas between central Indian protected areas (Dutta et al., 2015). We used data on resistance layer of habitat connectivity at the various widths - 20, 30, 50, 80, and 100 kilometers wide. We then classified resistance values into four equal intervals. For example when we used the corridor at 50 kilometers width, we categorize the corridor according to pixel values as corridor center (-12 to 16658), within corridor (16659 to 33328), and corridor edge (33329 to 49999). To assess whether resettled households are disproportionately locating into areas important for landscape-level connectivity, we overlay the spread of new settlement locations over our categorized resistance layer for habitat that form wildlife corridors in our study region. We then compare the number of resettled households to total non-resettled households present in each corridor category (according to underlying resistance value), reporting the total area under each corridor category.

Similarly, to assess whether current resettlement patterns are putting resettled households at disproportionate risks to HWC, we overlay resettlement locations with previously identified high-risk zones of HWC (Karanth et al., 2012). We specifically use the interpolated (kriged) risk probability maps with pixel values signifying probabilities of livestock predation or crop loss incident within a year (2010-2011) (Karanth et al., 2012). We bin pixel risk probability values into tens for our analyses (30 to 40 %, 50 to 60 % etc.). The analyses extent for HWC was the extent of risk data available and include only those resettled households and non-resettled households that fell within the extent of risk maps. We compare the number of resettled households that fall within high HWC zones to the total number of non-resettled households

within zones of HWC and report the total area under each risk category for livestock predation and crop losses. We used QGIS to conduct spatial analyses and manipulated raster files using R (packages – raster, sp, rgdal, maptools, rgeos, and dplyr).

Forest use comparisons and modeling livelihood factors

Based on our survey data, we compare mean estimates of forest use at the household level between resettled households and non-resettled neighbors at the new settlement locations in the KNP landscape. We use data according to appropriate seasons for forest use – for cattle ownership we use data across all seasons, for *tendu* trade we use only data from summer when *tendu* extraction occurs, and for forest food consumption we use data from summer as well as monsoon. Furthermore, we used linear, binomial and zero-inflated mixed effects models to explore which household livelihood factors are significantly associated with high or low forest resource use in the KNP landscape. We conceptually group the variables in our models into factors associated with reasons to rely on forests, access to forests and control variables (Table 1). Variables used in models are not collinear and were standardized (Appendix 3).

We use indicators such as household assets and sources of income as factors to explore which households are more likely to be associated with forest use according to their overall wealth. We use household location to measure distances to built-up areas (defined as areas containing a concentration of building and other structures, see – ISCGM, 2007a) and the core of KNP (strict protection areas within the larger administrative buffer). We included forest available per household within an eight kilometer forest use radius according to previous research that provides a reference radius for cattle grazing in the KNP landscape (Agarwala, 2014). We use

our forest available per household measurements to explore how forest availability associated with intensity of forest use. To measure forest available, we used data on tree cover data (see - Hansen et al., 2013) and then divided the number of tree cover pixels within an eight kilometer buffer around at the village location. We then divided the number of forest pixels within each eight kilometer buffer by the number of households at each village location as reported in the Indian government census (Census of India, 2011). We also included kitchen garden diversity as an indicator of livelihoods more aligned with traditional agricultural rural livelihoods. In our models, we controlled for other relevant variables including dependency ratio (measured as number of children / adults at the household in our study), survey season and recorded responses for HWC. Finally, we used cattle owned, *tendu* trade measurements and forest foods consumed in models when these variables were not the response variable. We included resettlement status as a fixed categorical effect to explore if resettlement had associations with forest use. We used *tehsil* (administrative block) as a random effect variable in our models to include any effects due to different administration across new settlement locations.

We ran models according to the distributions of our response variables – cattle owned (count), *tendu* participation (binomial), *tendu* effort (days collected multiplied by number of household members involved in collection - count), forest foods consumption (binomial) and types of forest foods consumed (count). We ran generalized linear mixed effect models to explore livelihoods associations with number of cattle owned per household. For our data on *tendu* trade and forest foods, we ran two types of models. To explore which household livelihood factors were associated with a household participating in *tendu* trade or consuming forest foods, we ran binomial mixed effects models. We use zero-inflated negative binomial mixed effects models to

explore which household factors are associated with more or less *tendu* effort or types of forest foods consumed (count data). We conducted all statistical analyses using R (packages – lme4, glmmTMB, glmmADMB, lmertest, coefplot2, and corrplot).

Results

When considering corridors at 50 kilometers width, 120 resettled households (27 percent of all resettled households) were located within identified wildlife corridors, inhabiting 36 villages with existing resident non-resettled populations (Fig. 2 (a)). We find that corridors cover 30% of the KNP landscape (extent from surveyed *tehsils*) inhabited by 20% of all non-resettled households (Fig. 2 (b)). Resettled households primarily settled outside of wildlife corridors (73%) and of the households within corridors (n =120) very few joined villages in the center of corridors (n = 6) (Fig. 2 (b)). We found few resettled households in corridors when considering wider or narrower corridors in our study landscape around KNP (Appendix 3).

However, even though resettled households are predominantly outside of wildlife corridors, many resettled households (382) are located in areas that face high risks of crop raiding and livestock predation (Fig. 3). Once again the HWC risks resettled households face are not due to resettlement into remote areas of the KNP landscape, instead there are high levels of HWC risks across the KNP landscape extending to at least to 20 kilometers outside of the KNP core boundary (Karanth et al., 2012).

Forest use by resettled households compared to non-resettled neighbors:

Resettled households have only marginally more livestock per household than non-resettled households (3.04 compared to 2.65 heads of cattle owned, p-value <0.01). The average *tendu* trade effort from resettled households is higher than non-resettled households. However, in terms of total forest use, fewer resettled households are involved in *tendu* leaf trade and consuming forest foods. Resettled households only make up one fourth the total households involved in *tendu* trade in our study (Appendix 3).

Livelihood factors associated with owning more cattle

Model results indicate that resettled households are associated with more cattle owned. Additionally, households further from towns, with kitchen gardens and more agricultural livelihoods (winter cropping and owning more land) are positively associated with owning more cattle. However, households with off-farm incomes (salaried or labor) are negatively associated with number of cattle owned. Proximity to the KNP core and living within the KNP buffer was not significantly associated with owning cattle (Table 2). Models controlled for dependents at each household and the random effects of being in different *tehsils*.

Livelihood factors associated with higher participation and efforts in tendu trade:

Resettled households are negatively associated with participation in *tendu* trade. As expected, the availability of tree cover at a given location and more nature reliant households (collect forest foods, have higher kitchen garden diversity, more cattle) are positively associated with participation in *tendu* trade. Salaried incomes are negatively associated with participation in *tendu* trade but seasonal labor is positively associated with *tendu* trade. Proximity to towns or

KNP core was not significantly associated with participating in *tendu* trade but households within the KNP buffer are negatively associated with participation in *tendu* trade (Table 3). Among the households that report *tendu* effort, we find that households closer to KNP and with larger land holdings are positively associated with the efforts expended on *tendu* trade, while those that grow winter crops are negatively associated with efforts expended on *tendu* trade (Table 3). When considering the zero-inflation in our measurements for household efforts in *Tendu* Trade (126 households out of 1302 report *tendu* effort), the high number of zeroes are positively associated with resettled households and households within the KNP buffer (Table 3).

Livelihood factors associated with incidence of and higher consumption of forest foods

Resettled households are negatively associated with consuming forest foods. In the KNP landscape there is a strong seasonal trend in forest food consumption - more households consume forest foods in monsoon (454) when compared to summer (144) and only seven households report consuming a single type of forest food in winter. Households with higher forest availability, more dependents and higher kitchen garden diversity are positively associated with the incidence of consuming forest foods (Table 4). Households further from KNP and within in the KNP buffer are negatively associated with counts of forest food types consumed (Table 4). Additional zeroes in our data of types of forest foods consumed are positively associated with summer season data and resettled households. Higher dependency ratios and kitchen garden diversity are negatively associated with zero-inflation in our counts of types of forest foods consumed (Table 4).

Discussion

Resettled households, under the current resettlement policy, have moved to areas with established villages predominantly outside of identified wildlife corridors. Resettled households do not influence baseline levels of forest resource use or HWC as they form small percentages (most locations < 10%) of existing populations in the locations they have moved into. Therefore, there are no disproportionate impacts on forests or risks of HWC (due to higher chance of wildlife encounters) due to high levels of clustering of resettled households in previously remote locations in our study around KNP. We stress that geographic patterns of resettlement might be different in other landscapes, resulting in lower or higher HWC in surrounding areas.

We find that many resettled households move to zones of high HWC, especially in the case of livestock predation, and would have to move further away from KNP to avoid these disadvantageous aspects of living near a protected area. Contrary to our expectations, resettled households do not face high HWC because of moving into previously uninhabited areas closer to non-protected forests used by wildlife. Spatial patterns of HWC differ for crop raiding and livestock predation, with the latter occurring across most locations surrounding KNP. Wildlife management in the area face the challenge of addressing HWC as rural populations in the KNP landscape continue to grow and increase their human footprint. Model results of forest use suggest that a reduction of opportunities to interact with dangerous wildlife (through cattle grazing or *tendu* collection) in the KNP landscape might occur with increasing opportunities for formal employment.

Resettled households own more cattle but report lower incidence of being involved in *tendu* trade and consume fewer types of forest foods when compared to their non-resettled neighbors. Resettled households are associated with more cattle in our comparisons and while statistically significant, the difference is not meaningful in practical terms. We find an overarching pattern in our study: households with salaried jobs are the households associated with low forest reliance (cattle and *tendu*), regardless of whether the household is resettled from KNP. A few studies have begun to address post-resettlement assessments in India and have found that with adequate avenues for off-farm incomes, resettled households show increases in household incomes as well as a preference for resettlement to avoid living under state restrictions (Harihar et al., 2014; Mahapatra et al., 2015). Additonally, in our study, households with more agricultural livelihoods have higher forest reliance in the KNP landscape. However, owning more assets is associated with owning more cattle. The association might have two reasons, a cultural preference for owning cattle when able and the advantage for large land owners that crop across the year as work animals. Overall, we stress that our results are specific to the KNP landscape in geographic extent as well as local context.

Conclusions

In the KNP landscape, resettled households have not clustered in large enough numbers to influence the existing pressures on non-protected forests or encounter rates of wildlife leading to HWC higher than non-resettled resident households. In terms of forest use per household, resettled households own more cattle (but not more than one animal) but fewer resettled households participate in *tendu* trade and consume fewer forest foods than their non-resettled neighbors. Pooling all surveyed households regardless of resettlement status, we find that

households with salaried jobs have less reliance on forest resources. Our results about forest use suggest that management might consider how changing rural livelihoods with increases in salaried jobs might alleviate pressures from wildlife corridors and lower wildlife encounters to aid the management of HWC around KNP.

We add to the extremely few studies quantifying post-resettlement impacts for conservation at a landscape and regional scale and find similarities with them in the importance of off-farm incomes' negative association with forest resource use (Harihar et al., 2014; Mahapatra et al., 2015). Case studies quantifying post-resettlement impacts on conservation and people can assess how conservation policies and social goals can be jointly considered for double-sustainability. In India, the potential for replication of studies under a standardized resettlement policy provides conservation and social science an unparalleled opportunity to address historical gaps in our understanding of resettlement impacts and trade-offs between rural livelihoods and forest use. While our conclusions are limited to resettlement around KNP, our inferences are useful for on-the-ground conservation and livelihoods across human-dominated landscapes where resettlement is a conservation policy. We stress the relevance of resettlement for landscape-level conservation beyond protected area boundaries. In the case of KNP, resettlement does not appreciably adversely affect corridors or put pressure on previously unused-forests. However, the result is context specific and could be different in other situations. Secondly, an empirical approach as used in this study allows evidence-based conclusions about impacts of resettlement at a landscape level. With resettlement as an ongoing conservation strategy to improve habitat in protected areas, examination of landscape-level impacts post-resettlement can help guide decisions for the well-being of both people and wildlife outside protected areas.

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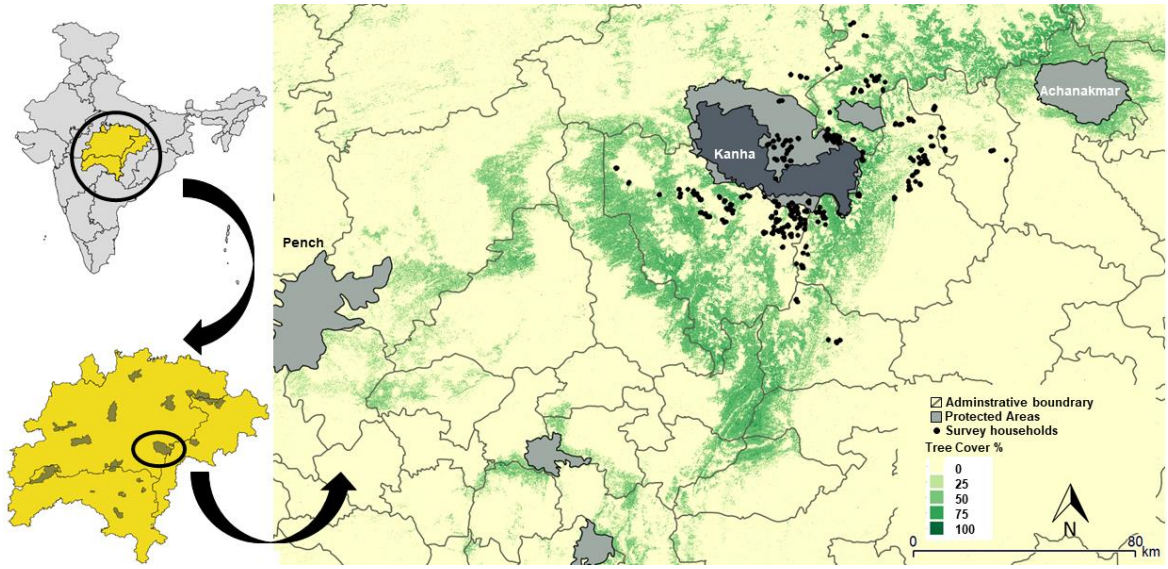
Figures and Tables

(a)



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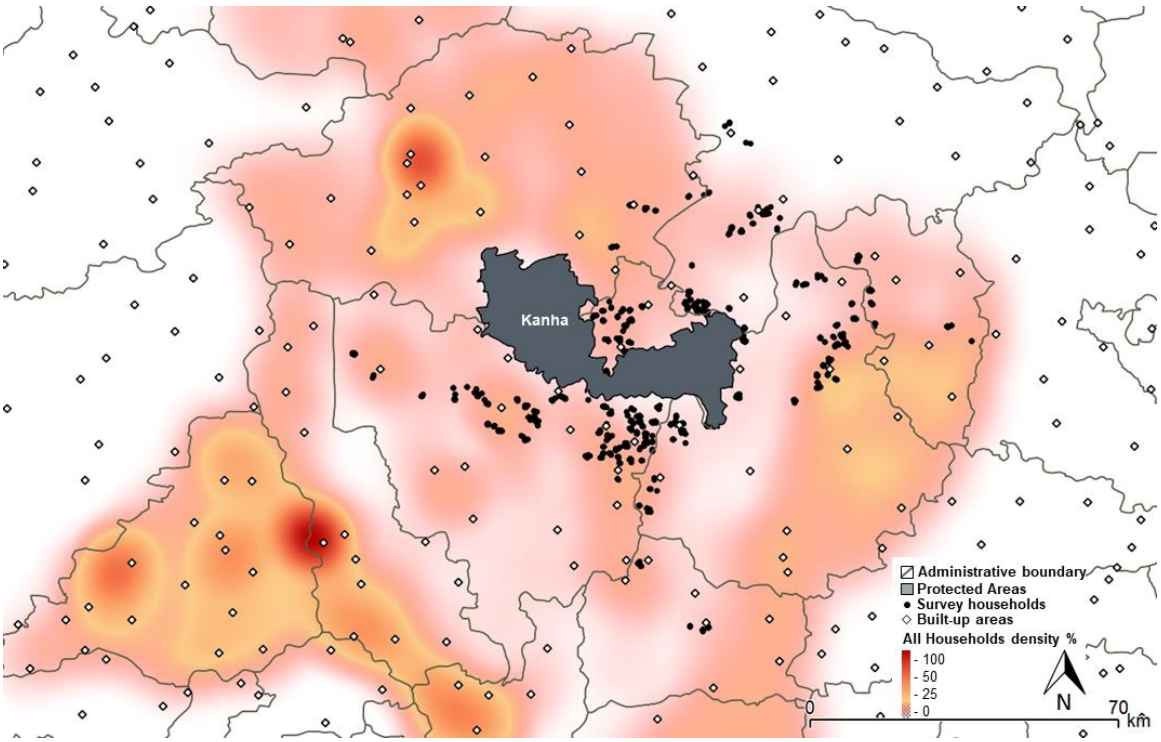


Figure 1: Study site within human dominated landscape with corridors for wildlife dispersal and resettlement locations.

(a) Inset maps show location of study site in central Indian landscape and tree cover percent (yellow to green background) that include non-protected wildlife corridors across the landscape (M. C. C. Hansen et al., 2013). KNP strictly protected core area in dark grey. (b) Heat map of number of households in villages and towns in the KNP landscape (maximum number of households is 15503) across study site in administrative blocks (*tehsils)*, built-up areas (white diamonds) (ISCGM, 2007a), households survey locations (black dots).

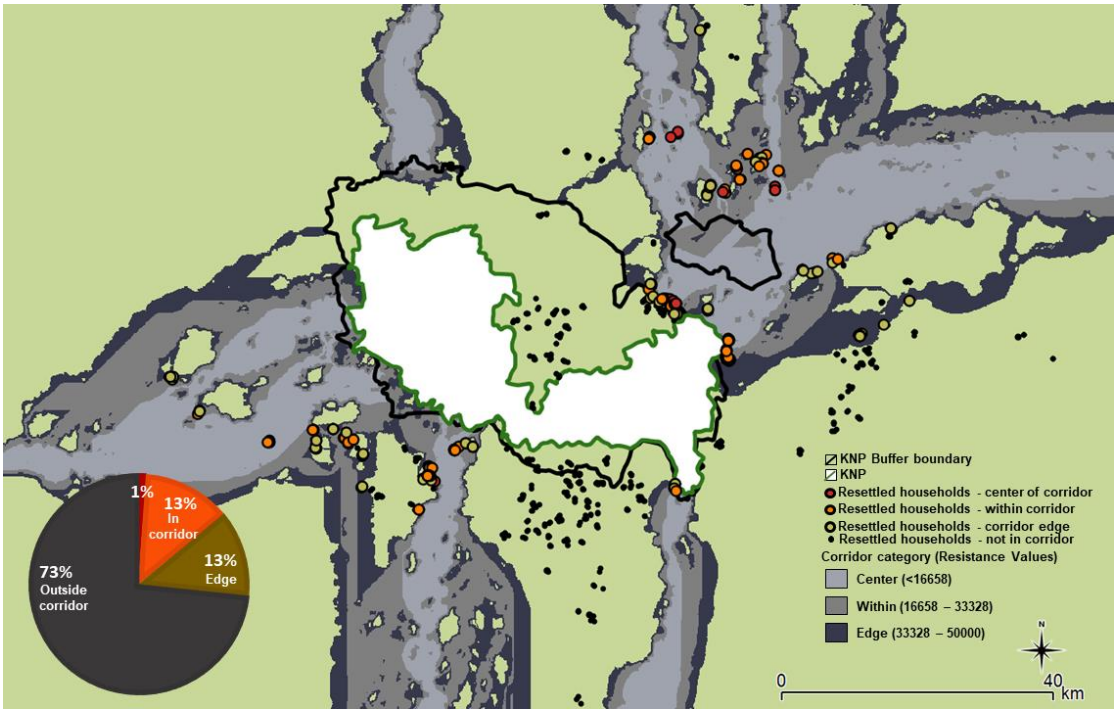
Table 1: Variables used in models grouped by rationale for including them in terms of reasons or requirement for forest resource, access to forest resource and control variables.

Within control variables we include - random-effect of tehsils, resettlement status, seasons as well as other livelihood indicator variables.

Variable	**Units**	**Data Source**
Reasons to use forests		
Assets	Weighted Score	Household Surveys and (Kishor & Parasuraman, 1998)
Jobs	Categorical	Household Surveys
Land Owned	Hectare	Household Surveys
Winter Cropping	Categorical	Household Surveys
Distance to Town	Kilometers	(ISCGM, 2007a) and QGIS
Availability of forest		
Forest available per capita	Tree cover pixels count	(M. C. C. Hansen et al., 2013) and Indian government census
Distance to KNP	Kilometers	QGIS
Within buffer	Categorical	QGIS
Other relevant data (FE = Fixed Effect, RE = Random Effect)		

Kitchen garden diversity (FE)	Number	Household surveys
Percent of crop raided (FE)	Percent categories	Household surveys
Livestock killed (FE)	Number	Household surveys
Cattle owned (FE)	Number	Household surveys
Tendu effort (FE)	Man hours (household members participating * number of days collecting *tendu*)	Household surveys
Forest foods consumed (FE)	Count	Household surveys
Season (FE)	Categorical	Household surveys
Dependency ratio (RE)	Children / Adults	Household surveys
Resettlement status (RE)	Categorical	Household surveys
Tehsil (administrative block) (RE)	Categorical	QGIS

(a)



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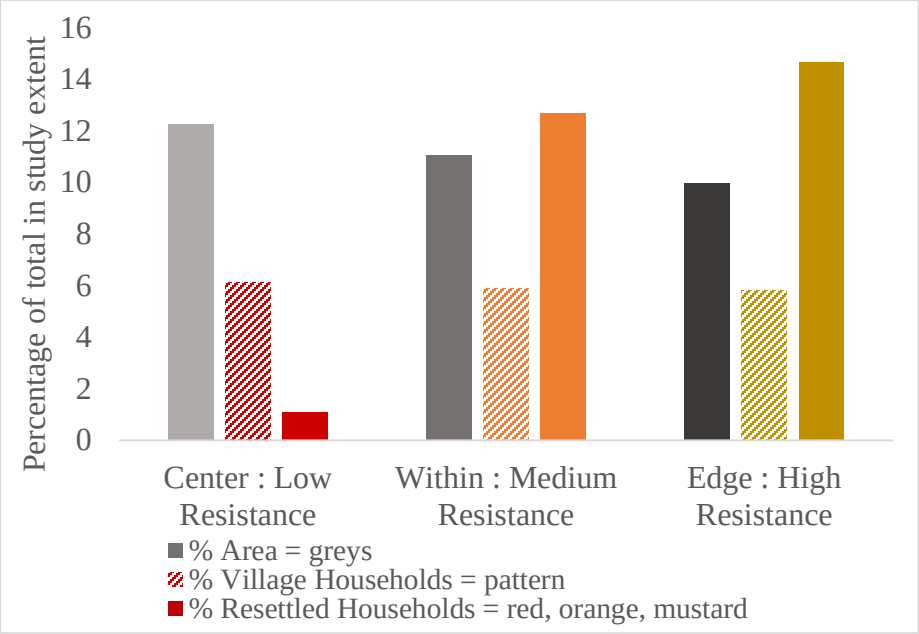

Figure 2: Comparisons of resettled households with existing non-resettled households within wildlife corridors.

(a) 120 of all resettled households (colored circles) fall within the bounds of previously identified wildlife corridors at 50 kilometers width (corridor data from - Dutta et al. 2015). KNP core area shown as white polygon with green outline, buffers include transparent polygons with black outlines. Resettled households outside of corridors depicted as black dots. (b) Overall, corridors cover 33% of the KNP landscape at the 50 kilometer width and have around 18% of all non-resettled households as well as 27% of all resettled households residing within corridor areas. Resettled household predominantly have inhabited edges and corridor areas that are not the center (least resistance value).

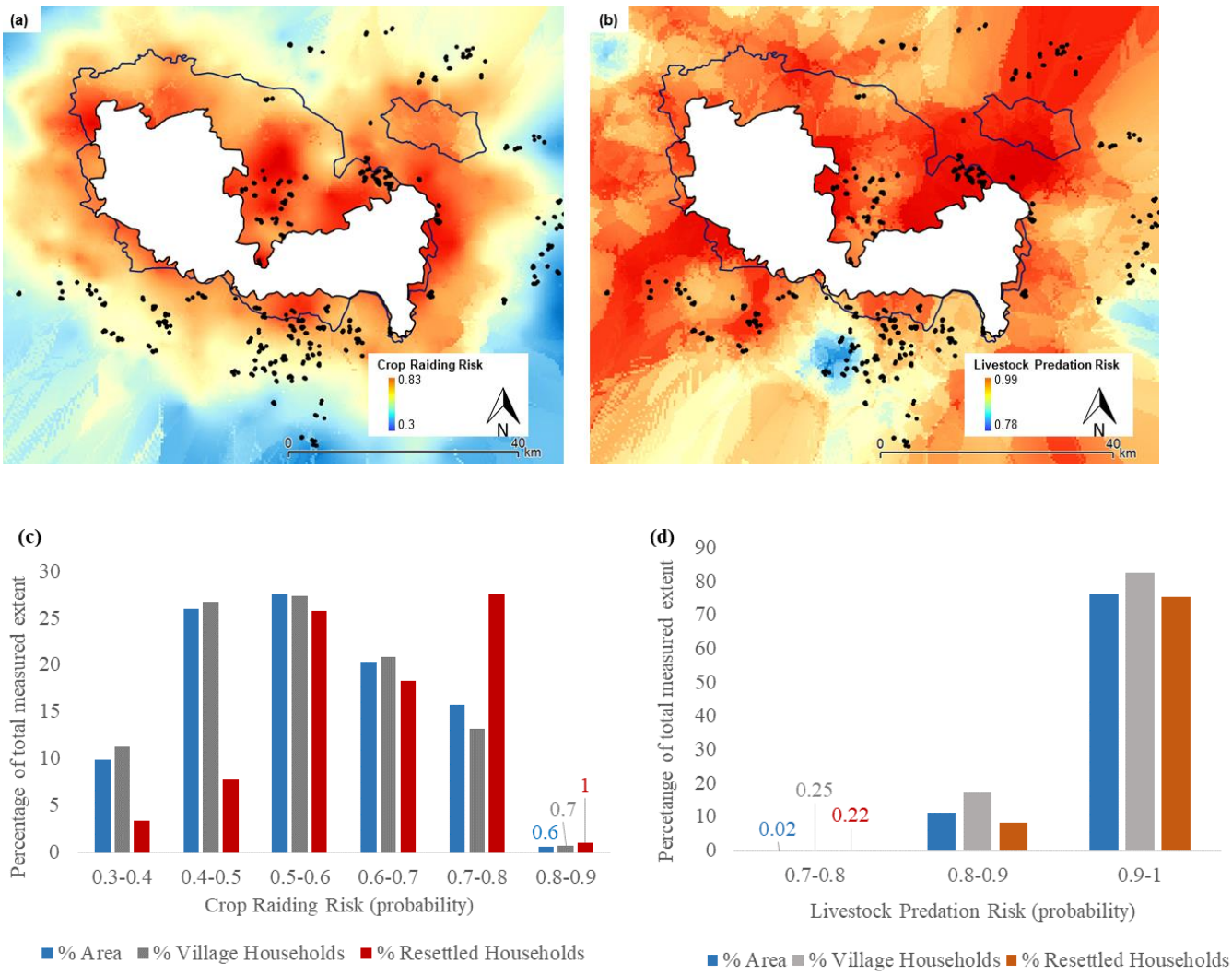

Figure 3: Human-wildlife conflict risks to resettled households and non-resettled households in the KNP landscape.

382 of all resettled households fall within identified regions of probable crop and livestock loss within a year (2010-2011) (risk probabilities from - Karanth et al. 2012). We could not assess HWC risks for 68 households that fell outside geographic extent of HWC data. Maps depict geographical areas of human wildlife conflict (HWC) risks around KNP (white polygon), resettled households (black dots) and KNP administrative buffer areas (blue outline polygons) (a, b). Risk probabilities of livestock and crop loss for households within these areas given in bar graphs – contrasting existing household numbers with those that resettled into these areas (c, d).

Table 2: Model results of year round data on cattle from all surveyed households (n = 3458).

Generalized linear mixed effect model results in table. Tehsil (8, administrative blocks) as random effect. Significance of predictors = around 0.05 '.' / <0.05 * / <0.01 ** / <0.001 ***

HEADS OF CATTLE = response as count	**Estimate**	**Standard deviation**
Assets	0.14 ***	0.008
Forest per household in village (8 kms radius)		
Dependency ratio (Children/Adults)	-0.04 ***	0.01
Distance to town	0.02 *	0.01
Distance to KNP core perimeter		
Jobs - salaried	-0.39 ***	0.05
Jobs - labor	-0.13 ***	0.02
Jobs - seasonal labor	-0.36 ***	0.06
Respondent type (resettled)	0.12 ***	0.02
In buffer		
Land owned	0.04 ***	0.007
Winter cropped fields	0.17 ***	0.02
Caste code		
Crop raiding percent	0.04 ***	0.009
Livestock killed	0.03 ***	0.006
Garden diversity	0.08 ***	0.009
Marginal R sq	0.10	
Conditional R sq	0.10	

Table 3: Model results for *Tendu* trade in the KNP landscape.

Modeling participation in *Tendu* trade as a binomial mixed effects model and zero-inflated negative binomial mixed effects model for data collected in summer (n = 1302) across eight tehsils (random effect). SD = Standard Deviation, Significance of predictors= around 0.05 '.' / <0.05 * / <0.01 ** / <0.001 ***

	***Tendu* Y/N**		***Tendu* Effort (counts)**		***Tendu* Effort (0-inflation)**	
	Estimate	**SD**	**Estimate**	**SD**	**Estimate**	**SD**
Assets						
Forest per capita (8 kms)	0.12 '.'	0.07				
Dependency ratio			-0.19 *	0.08	-0.18 *	0.09
Distance to town						
Distance to KNP core perimeter			-0.21 *	0.09		
Jobs – salaried	-1.41 *	0.56				
Jobs – labor						
Jobs - seasonal labor	0.52 *	0.26			-0.81 *	0.34
Respondent type (resettled)	-1.31 ***	0.16			0.89 ***	0.21
In buffer	-0.51 '.'	0.26			0.70 *	0.31
Land owned			0.09 *	0.03	-0.21 *	0.1
Winter cropped fields			-0.53 **	0.17	-0.59 **	0.2
Cattle	0.17 *	0.07				
Forest Foods	0.17 *	0.06				
Crop raiding percent						
Livestock killed	0.11 '.'	0.06			-0.11 '.'	0.06
Garden diversity	0.15 *	0.06				
Over dispersion			1.41			

Table 4: Model results of forest food consumption in the KNP landscape.

Modeling incidence of consuming forest foods (binomial data) and types of forest foods consumed (count data) as a binomial mixed effects model and a zero-inflated negative binomial mixed effects models respectively. Using data collected in summer and monsoon (n=2342) across eight tehsils (random effect). SD = Standard Deviation, Significance of predictors= around 0.05 '.' / <0.05 * / <0.01 ** / <0.001 ***

	Forest Foods y/n		**Forest Foods (count)**		**Forest Foods (0-inflated)**	
	Estimate	**SD**	**Estimate**	**SD**	**Estimate**	**SD**
Summer season	-1.80 ***	0.11			1.93 ***	0.27
Assets						
Forest Available (8 kms)	0.15 **	0.05				
Dependency ratio	0.11 *	0.05			-0.23 *	0.1
Distance to town						
Distance to KNP			-0.12 *	0.06		
Job salary						
Job labor						
Job seasonal labor						
Resettled	-0.25 *	0.1			0.40 *	0.2
In buffer			-0.26 '.'	0.16		
Land owned						
Winter cropped fields						
Cattle						
Garden diversity	0.35 ***	0.05	0.07 '.'	0.04	-0.46 **	0.15

CHAPTER 5 - CONCLUSIONS

Resettlement from protected areas continues to be a prevalent conservation policy to create inviolate areas for biodiversity conservation, especially as external pressures from human activities increase on remaining natural areas (Agrawal & Redford, 2009; Karanth et al., 2013; Lamichhane et al., 2017; Lasgorceix & Kothari, 2009). However, the success of resettlement as a conservation policy will largely depend on addressing impacts on people's livelihoods (including reliance on non-protected natural resources) and well-being around increasingly insular protected areas in human-dominated landscapes (Cernea & Schmidt-Soltau, 2006; Harihar et al., 2015; Kabra & Mahalwal, 2014; Naughton-Treves et al., 2005; West et al., 2006). This dissertation examined the impacts of resettlement on food security, non-protected resource use and human-wildlife conflict within the local context of tiger conservation around Kanha National Park (KNP) in central India. By quantitatively addressing both food security as a multidimensional measurement of human well-being and conservation at the landscape level, I hope that my dissertation has improved understanding of how resettlement in human-dominated landscapes can achieve social and conservation goals.

Resettlement impacts on food security are robustly measured with a keen understanding of the four pillars of food security - food availability and the abilities of households to access as well as utilize the available foods at their new settlement locations in stable patterns (Jones et al., 2013; Leroy et al., 2015). Chapter 1 illustrates that resettlement in the KNP landscape has resulted in people moving into existing villages where resettled households have similar food consumption as their non-resettled neighbors. However, the overall pattern of FCSs show high food insecurity,

including regular use of coping strategies to battle food scarcity, across resettled as well as non-resettled households. The results in Chapter 2 highlight the importance of financial capital, within the KNP landscape, for households to attain higher FCSs and illustrates household reliance on social as well as natural capital in times of financial stress. Together, both Chapter 1 and 2 point to the importance of stable incomes to household food security and the supplementary role kitchen gardens play to alleviate food insecurity in the KNP landscape regardless of resettlement status.

Similar to the influence of livelihoods on food security, livelihood opportunities are significantly associated with resettlement impacts on non-protected forest resource use and consequently human-wildlife conflict (Harihar et al., 2015; Kabra & Mahalwal, 2014; Mahapatra et al., 2015; Milgroom et al., 2014). In Chapter 3, I show that resettlement locations across the KNP landscape affect the livelihood opportunities to use non-protected forests and the risks of human-wildlife conflict. Resettled households join existing villages in very small percentages and report lower forest use than their non-resettled neighbors. Consequently, resettled households do not have a disproportionate impact on habitat connectivity between KNP and neighboring protected areas. I conclude that resettlement from KNP has not resulted in substantial pressures on conservation-relevant non-protected forests in the KNP landscape. However, because dispersing tigers do not always stay within the bounds of suitable habitat (Krishnamurthy et al., 2016), the current undirected resettlement results in the majority of resettled households moving into high human-wildlife conflict zones due to their proximity to KNP. Increasing stable incomes in the landscape also alleviates non-protected forest use by all households and potentially decreases opportunities to encounter tigers dispersing from KNP.

This dissertation highlights the importance of studying undirected resettlement patterns at the landscape level to understand the influence of resettlement on human well-being (here - food security) and conservation goals. A few quantitative studies of resettlement impacts consider faunal recovery in habitats vacated within protected areas (Harihar et al., 2008; Lamichhane et al., 2017), though these recoveries are largely documented by park managers. From a landscape level perspective, there is a growing recognition of the importance of understanding the impacts of resettlement on social and conservation goals (Harihar et al., 2015; Karanth, 2007; Lam, Paul, & Sarma, 2016; Mahapatra et al., 2015; Milgroom et al., 2014). However, studies of resettlement that consider impacts on well-being, livelihoods and landscape scale conservation goals together are rare or focused on a small sample of locally affected populations. The challenges of past endeavors to study resettlement are overcome in part due to recent initiatives to document resettlement and advances in measurements of well-being (Harihar et al., 2014, 2015; Kabra, 2009; Kabra & Mahalwal, 2014; Karanth, 2007). Analyses of resettlement that integrate well-being measurements and conservation impacts outside the administrative boundaries of protected areas can influence the interpretation of successful resettlement.

I hope that the results of this dissertation are useful for people making and implementing policies about resettlement from protected areas. National governments and local managers juggle multiple interventions to try to achieve social and conservation mandates. For example, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act (FRA), 2006 provides for the restitution of deprived forest rights across India, including both individual rights to cultivated land in forestland and community rights over common property

resources. Simultaneously, the National Tiger Conservation Authority (NTCA) sets policies about resettlement from protected areas with the aim of creating inviolate spaces for tigers and includes provisions that align with the FRA. The implementation of the NTCA resettlements from National Parks in India remains contentious due to varying interpretations of guidelines and the lack of information on post-resettlement impacts on people (Kashwan, 2013; Sekar, 2016; Shahabuddin & Bhamidipati, 2014). Finally, the National Food Security Act has the objective to provide for food and nutritional security, by ensuring access to an adequate quantity of quality food at affordable prices. These seemingly contradictory goals could be achieved through implementing measures identified through assessments such as ours that locally tailor interventions to aid food security, e.g. kitchen gardens, and conservation goals. The NTCA could also consider the evidence from this dissertation on stable incomes as a conservation priority to reduce unsustainable forest use by local populations. KNP managers could alleviate food insecurity and lower use of natural resources by increasing opportunities for off-farm salaried employment – for resettled and non-resettled households.

The NTCA and KNP managers could use findings from this dissertation to consider approaches to improve food security in resettled households. Results suggest that increase in stable incomes through salaried employment potentially allow households to improve their dietary diversity (Food Consumption Scores) year-round. Managers responsible for resettlement might work together with other governmental authorities such as local municipalities, rural development authorities and state governments. Protected area managers, with the aid of local government bodies, could consider providing census data on employment opportunities and land prices within census blocks to households prior to resettlement. The implementation of resettlement

with monetary compensation is likely to succeed when resettled households are able to make informed choices, weighing the costs and benefits of remaining close to the protected area or moving further away. The geographical spread of resettlement locations from this dissertation points to additional reasons to work with local governmental bodies who are in-charge of rural development and employment. The forest department trains to manage forest resources and extends their mandate to implement the current resettlement. However, the forest department is likely to face challenges in continuing to monitor households who choose to move further away from forests (protected or non-protected). Additionally, the current resettlement policy requires households to provide proof of buying land (using part of monetary compensation) as part of stipulated conditions to receive all remaining monetary compensation in order to secure an asset as part of the transition into the wider local community. Results from the dissertation suggest that the relaxation of the clause or a diminished requirement when households are able to provide proof of stable and government verified salaried employment could increase freedom for diversified incomes around KNP. Diversified stable incomes are associated with increases in household FCSs and decreases in reliance on forests in the KNP landscape. The landscape specific suggestions for KNP from this dissertation hinge on the availability of data on employment, levels of human-wildlife conflict surrounding the protected area, and overall well-being status of human communities surrounding the protected area. Moreover, suggestions from similar studies are likely to be context-specific in other landscapes. The Kanha Forest Department, working with other government authorities, can enhance opportunities for stable incomes year round, potentially to alleviate seasonal worsening of food security in the landscape in monsoon. The Kanha Forest Department might consider utilizing tourism infrastructure for aid during monsoons by working out social aid opportunities with local municipalities. In many

landscapes, the Forest Department has already implemented resettlement but remains the main monitoring agency for resettled households. Finally, results from this dissertation might allow Forest Departments to provide a robust scientific study as an independent third-party basis for working with local municipalities and rural development government bodies. Direct applications from this dissertation require initial pilots to ensure local context continues to inform how resettlement, as well as social and conservation goals could be successful.

This dissertation also provides opportunities for already resettled households and their neighbors to understand the costs and benefits of their current geographic location in the KNP landscape. Building on the results of this work, researchers and local groups might run pilot programmes to ascertain the gains to food security from kitchen gardens and enhancing access to information about off-farm employment. There is growing evidence that in many countries and landscapes enhancing market access through off-farm incomes and increasing homestead production across food groups is likely to yield better nutritional outcomes (Frelat et al., 2016; Koppmair, Kassie, & Qaim, 2017; Sibhatu, Krishna, & Qaim, 2015). Village panchayats (elected governing body at village level) could encourage local organizations and researchers to use the dissertations findings for landscape pilots on the mechanisms to alleviate food insecurity and human-wildlife conflict while enhancing avenues for stable incomes. Non-Governmental Organizations (NGOs) and research networks could use results from this dissertation to engage in landscape-wide studies leading to science based applicable interventions. NGOs working from household to landscape scale can use the results to enhance stable alternate livelihoods and household kitchen gardens. NGOs and researchers working the landscape could also use this dissertation to solicit resources to conduct pilot studies to plug gaps in our understanding of local dynamics –

especially understanding of *tendu* trade networks and quantify the contributions of *tendu* to households' well-being as well as impacts on conservation goals.

Our results illustrate that considering social and ecological resettlement impacts within an existing system can aid in alleviating pressures on forest resources, manage human-wildlife risks and benefit local livelihoods. Avenues for steady incomes in ecotourism off-season would be valuable to alleviate food insecurity in households living around KNP. Our results reinforce that considerations of local context and beneficial outcomes for local populations lead to conservation success (Oldekop et al., 2016). Managers can encourage the use of the interdisciplinary methods demonstrated in this dissertation to study other landscapes where resettlement affects both people and landscape-wide conservation.

Finally, this dissertation illustrates the insight gained by taking an interdisciplinary landscape-wide observational approach to understanding the impacts of resettlement on people and conservation. Experimental manipulations of coupled human-nature systems are unethical in many situations and logistically difficult with many confounding factors due to complex human behavior. Documentation of resettlement, satellite data, availability of baseline data about local populations, and advances in measurements of human well-being can now allow for robust studies that overcome the challenges of small sample sizes and historically poor documentation post-resettlement. The approaches in this dissertation are powerful in detecting significant associations between well-being (here – food security), local livelihoods, and conservation outcomes. However, our methods are limited in their ability to explain the mechanistic processes that lead to the observed significant associations. Future research could investigate the social and

ecological processes behind the patterns detected in this study. For example, detailed studies of household incomes and remittances in the KNP landscape could illustrate mechanisms of household reliance on forest resources as well as processes governing seasonal food insecurity in monsoon (Fischer & Chhatre, 2015). Studies of local food systems might provide insights into more nuanced interpretation of standardized food consumption metrics within the local context (for example – habitual low intake of meats in predominantly vegetarian community). Studies of household choices could shed light on the cultural preferences to increase cattle as assets beyond work animals or continued *tendu* trade alongside aspirations for modern urban lifestyles (Harihar et al., 2015). Studies on tiger ecology and tiger behavior could provide insights on why zones of high human-wildlife risks do not always coincide with suitable habitats.

Resettlement, vulnerable livelihoods, forest reliance and human-wildlife conflict are important and interacting parts of managing protected area landscapes, especially apparent in human-dominated systems in many developing nations. With nuanced theoretical frameworks (for example - the five capital model of sustainable development and zones of interaction framework for landscape management (DeFries et al., 2010; Goswami & Paul, 2012), researchers are beginning to empirically evaluate people-park interactions. The evaluations of people-park interactions also inform researchers about the changing aspirations and resource use of local populations in human-dominated landscapes. I hope that this dissertation contributes to our understanding of resettlement impacts for people and conservation, and that it aids future efforts to manage protected areas within increasingly human-dominated landscapes for the benefit of people and wildlife.

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APPENDIX 1 – SUPPLEMENTARY MATERIALS FOR CHAPTER 2

1. Markets

Table 1 - Market data across the study region. Monsoon = M; Winter = W; y = present in market; All prices in Indian Rupees.

	Gadhi		Baihar		Mandai		Malajkhand		Bodla		Mangli		Mohgaon		Baijalpur	Larbakki	Chhipli
Food Group	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	M	M
Tubers	20	5	20	8	20	7	20	8	17	9	20	10	20		25	20	17.5
Pulses	80	78	63	79	89	87.86	84	87.71	83	87.14	88.5	87.56	83.5	87.14	93.75	83.88	78
Red Meat	340	3000	345	3000	350	350	340	345	340	355	340	350	340	345		345	345
Chicken	147	135	140	140	145	145	145	150	140	140	140	135	140	145	120	150	140
Eggs							60		55						60		
Fish	176	150	130	135	135	165	135	177.5	135	165	110	165	95	160	160	120	135
Dry Fish	120	120		120		100		110		117.5		110	65	110			65
Vegetables	32	8	33	9	27	10	27	10.14	28	10.86	25.28	9.14	30	10.75	37.5	25.31	25.36
Pirahi Mushrooms					275		365		365				265			425	
Putpura Mushrooms	80		80		80		130		145		85		135			95	85
Fruit							63								100		35

Snacks	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y
Oil	85	88	95	90	113	85	97	87	97	87	95	85	90	82	95	90	110
Sugar	32	40	40	40	37	42	37	45	37	45	35	50	35	42		37.5	
Salt	17	5		5		7.5	19	7	20	9.5	19	7.5		8			19

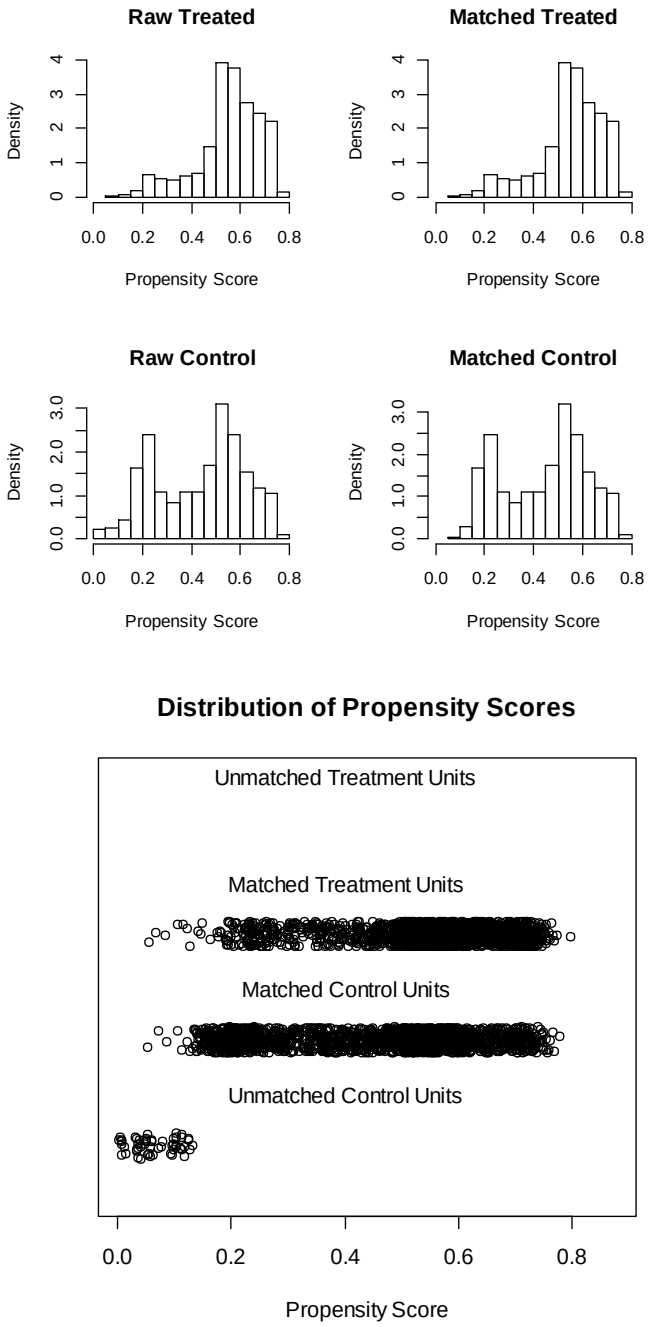
2. Propensity score matching (without replacement) used for balance testing in our data.

Variables used to match resettled and non-resettled households (output histograms and jitter plots below comparison table):

Land owned + assets + shock incidence + winter crop types (count data – proxy for quality of land) + winter crop (y/n – quality of land) + years of education + number of adults + number of children + number of relatives in vicinity + tribe and caste (categorical) + % of wheat crop sold

Table 2: We report the means and standard deviations of the characteristics in the variables used for propensity scoring to emphasize that resettled and non-resettled households are comparable in our study.

Variable	**Mean Resettled (SD)**	**Mean Non-resettled (SD)**
Land Owned	2.0 (1.6)	2.5 (4.8)
Assets	5.2 (4.3)	5.5 (4.7)
Shock Incidence	0.02 (0.1)	0.03 (0.1)
Winter Crop Types	0.4 (0.7)	0.5 (0.8)
Winter Crop (y/n)	Categorical	
Years of education	5.8 (4.7)	7.2 (5.2)
Number of adults	3.6 (1.8)	3.8 (1.8)
Number of children	1.9 (1.4)	1.9 (1.4)
Number of relatives	1.5 (4.0)	2.5 (6.0)
Tribe & caste	Categorical	
% of wheat crop sold	0.4 (3.9)	0.8 (6.0)



Output histograms and jitter plots show balance in study in terms of comparing resettled (treatment) to non-resettled (control) households with the heavy penalization in one-to-one matching.

3. Variable Names as used in modeling

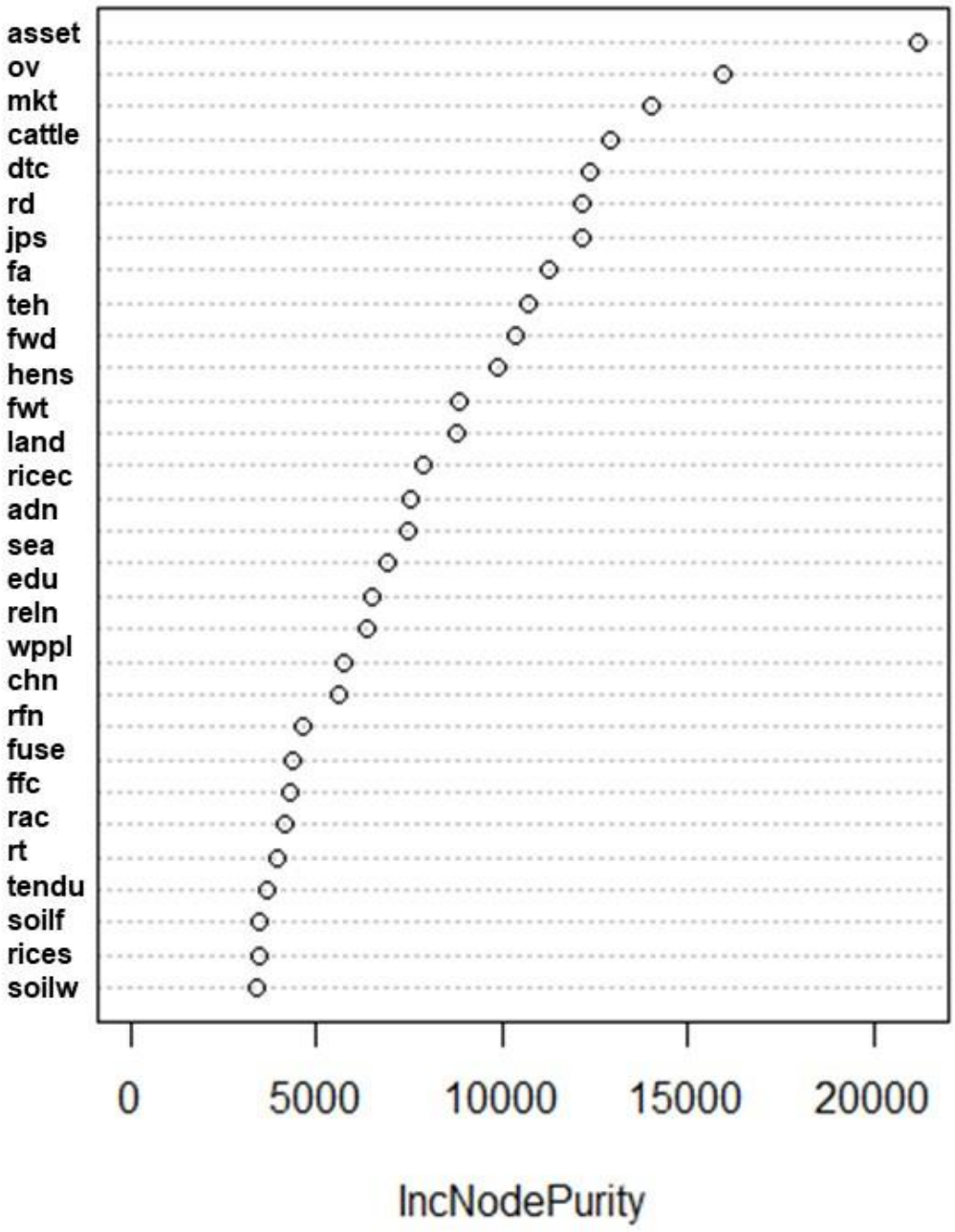
Variable Name	Explanation / Longer name
adn	Number of adults
asset	Asset index score
cattle	Heads of cattle
chn	Number of children
dc	Number of children suffering diarrhea
dd	Number of days child spent suffering diarrhea
dtc	Distance to KNP core area - euclidean measured in QGIS
edu	Education level - highest in household
fc	Number of children suffering fever
fd	Number of days children spent suffering fever
ffc	Forest food count
fwd	Fuel Wood distance - reported by respondent on survey
fwt	Fuel Wood time taken - reported by respondent on survey
gdiv	Number of types of veg grown in garden
goat	Number of goats
hen	Number of hens
ht	House material - mud / brick+concrete / mixed
jps	Job profile: income sources (labour / agriculture / cattle / salaried job / poultry etc.)
kero	Kerosene as cooking fuel yes / no
killn	Number of livestock killed by large carnivore
land	Land owned
lpg	LPG as cooking fuel yes / no
midday	Number of days children sent to midday meals at school
mkt	Distance to market - euclidean measured in QGIS
ov	Origin village
pcr	% crop raided by animals
pig	Number of pigs
rd	Distance to road - euclidean measured in QGIS
reln	Number of relatives in the village
resi	Time in months since resettlement
rfn	Number of resettled families from KNP in the same village
ricec	% rice crop consumed annual
ricek	% rice crop stored annual
rices	% rice crop sold annual
riv	Distance to river - euclidean measured in QGIS

shock	Incidence of shock event in the last year (death of family member / natural calamity)
soilf	Soil fertility perception as reported by land owner
soilw	Water retention capacity of land owned
teh	Tehsil
tendu	Number of people * number of days tendu collection effort
wheatc	% wheat crop consumed annual
wheatk	% wheat crop stored annual
wheats	% wheat crop sold annual
winterct	Winter crop type count
wppl	Number of people collecting water for household

4. Random forest results showing important variables under various data groupings:

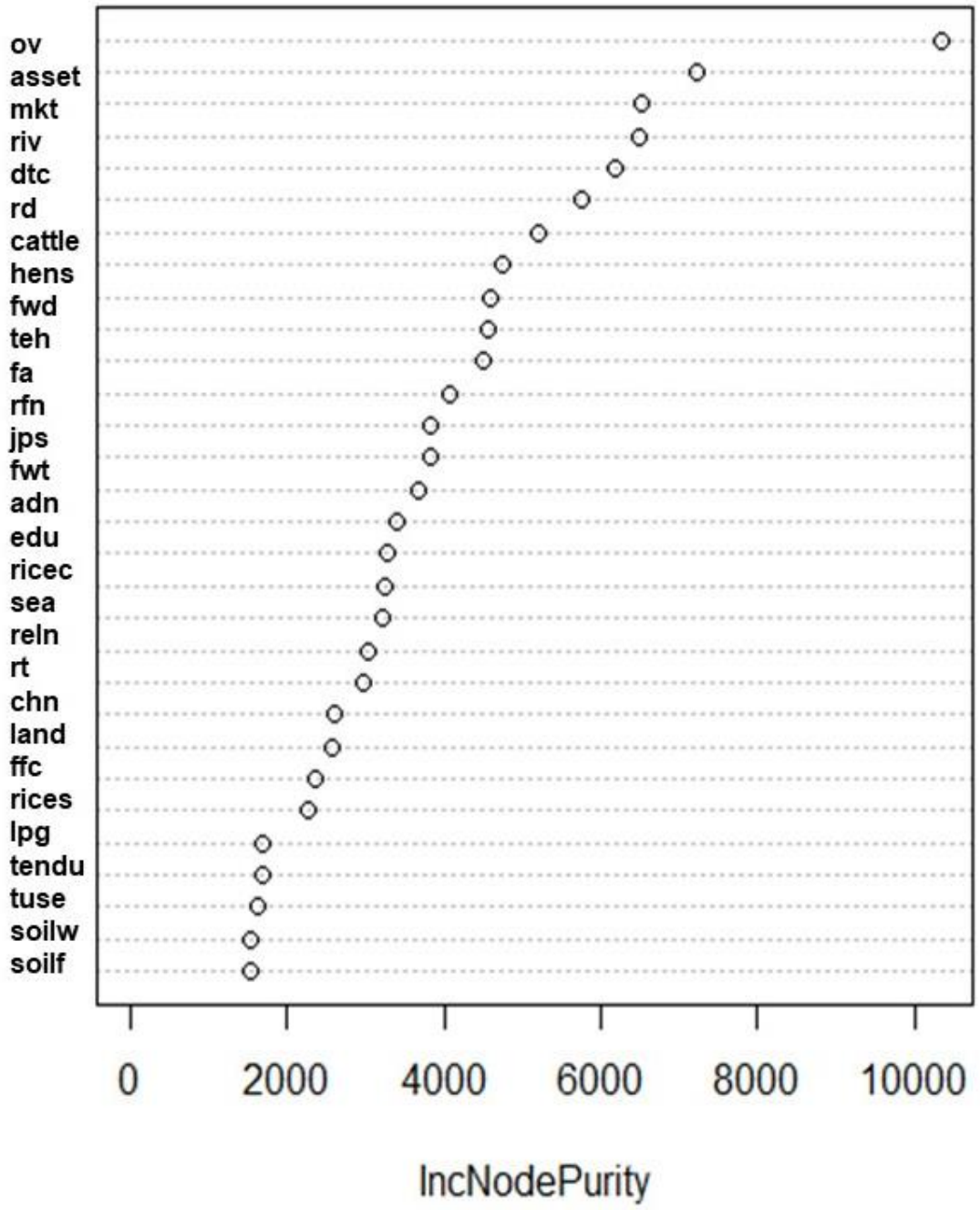
FCS ALL Households in our study

(variables to do with resettlement were given a constant dummy value for non-resettled households)

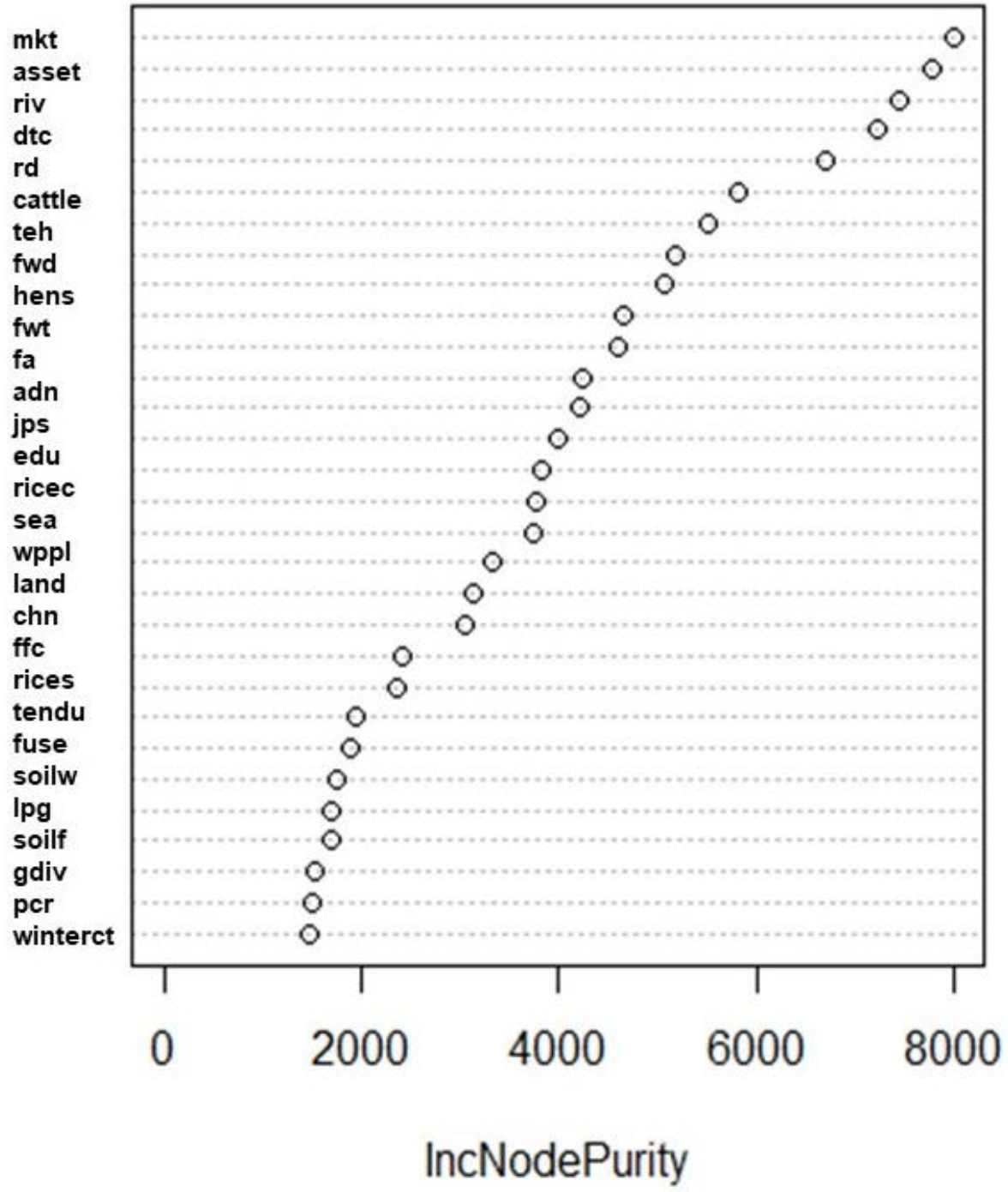


FCS Resettled with resettlement variables

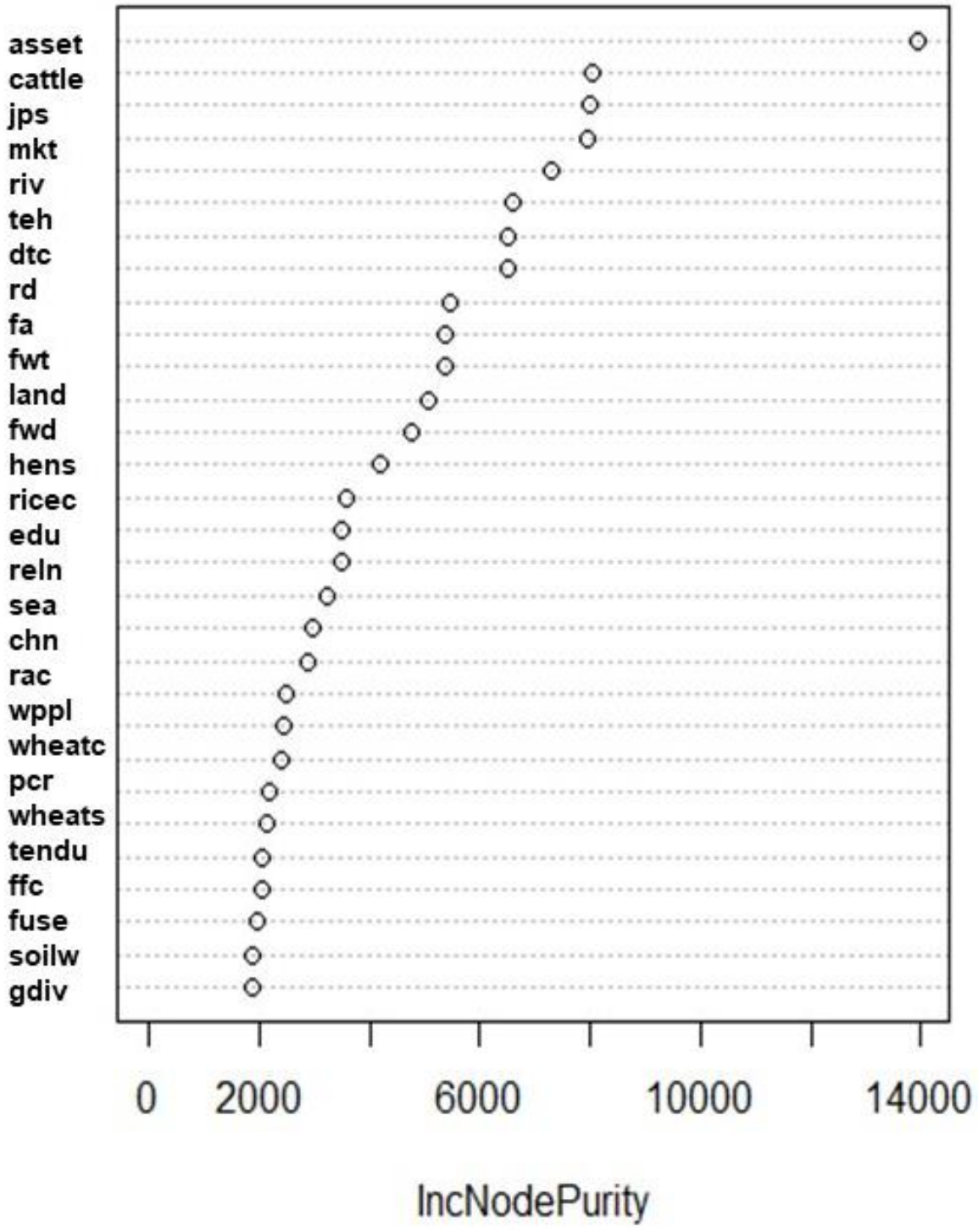
(origin village, nearby resettled families , residence time)



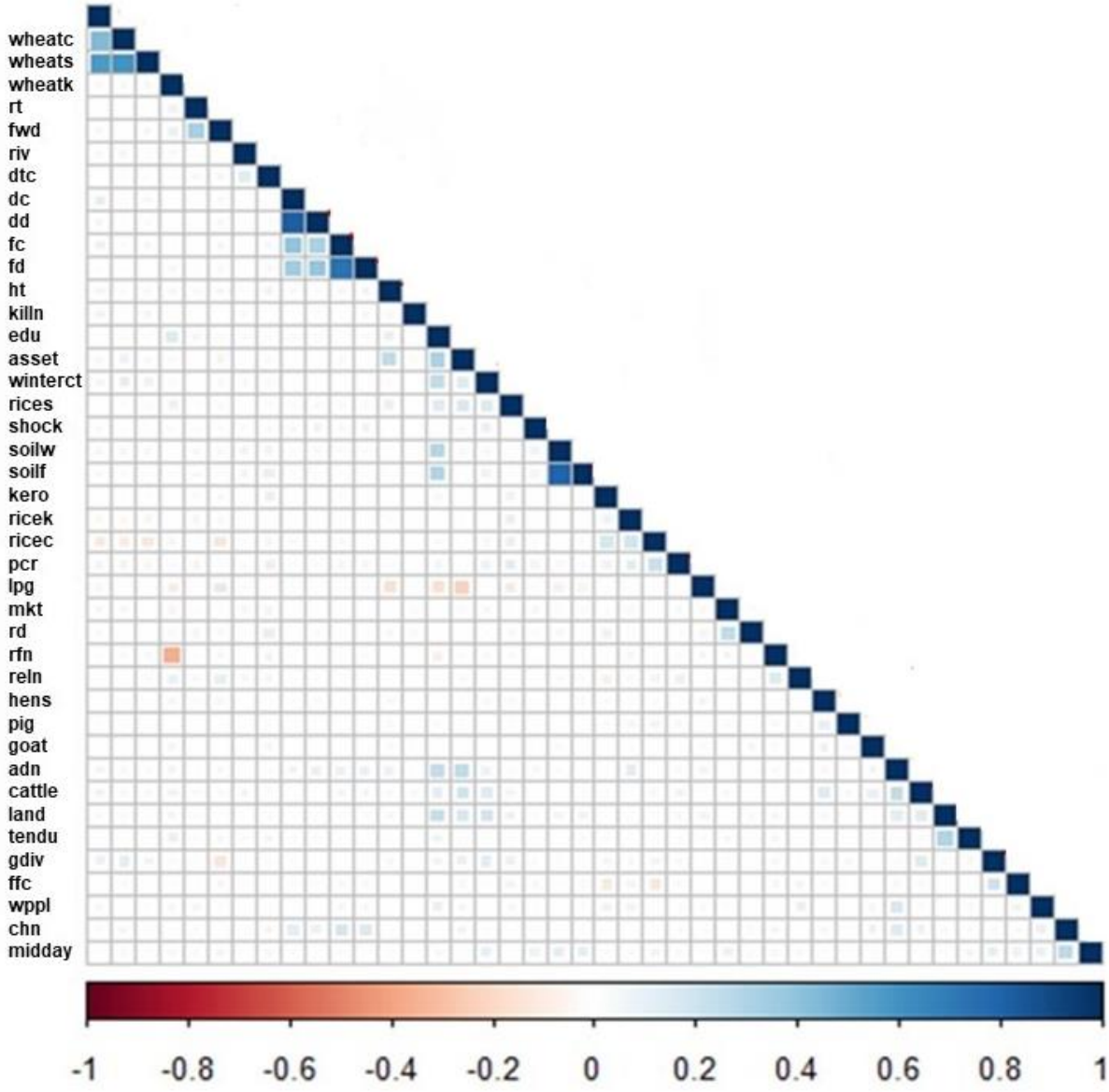
FCS Resettled with no resettlement variables (origin village, nearby resettled families , residence time)



FCS for non-resettled households only



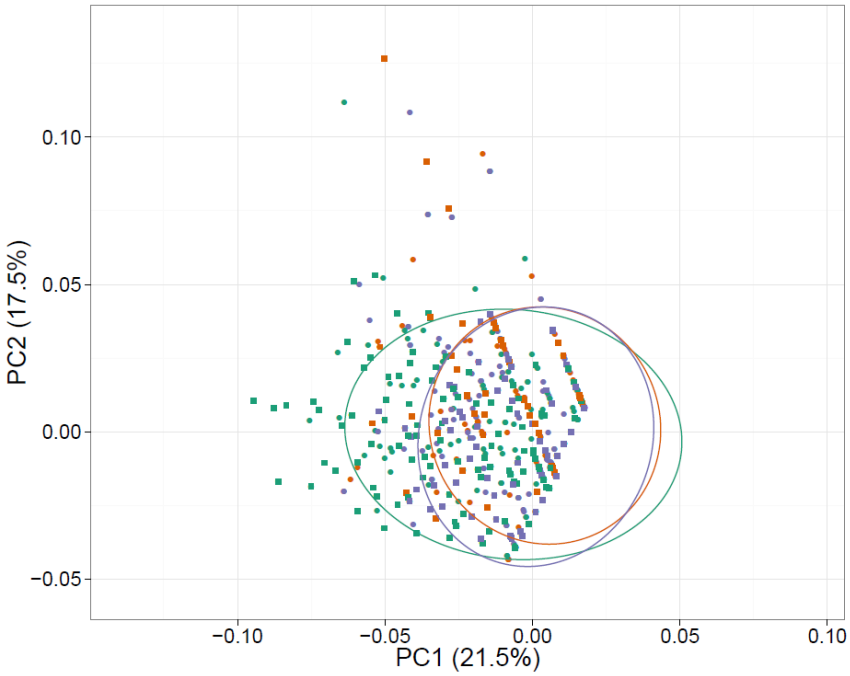
5. Variables used in models correlation matrix



6. CSI by tehsil and season

	Summer			Monsoon			Winter		
Tehsil	Resettled	Non-resettled	P-value	Resettled	Non-resettled	P-value	Resettled	Non-resettled	P-value
Baihar	2.0	2.4	0.5	6.6	2.9	**0.001**	5.4	2.5	**0.005**
Bicchiya	2.4	2.8	0.7	4.4	3.7	0.4	2.9	2.8	1.0
Birsa	1.4	1.3	0.9	4.9	4.2	0.5	3.7	3.9	0.9
Bodla	1.9	1.6	0.6	3.5	2.8	0.3	2.4	2.4	1.0
Chhuikhadan	*5.7*	*2.5*	*0.056*	2.4	0.9	0.3	1.3	1.4	0.9
Panderia	3.0	1.2	**0.045**	3.9	1.0	**0.005**	2.4	1.6	0.4
Paraswada	*1.7*	*0.5*	*0.055*	2.2	3.5	0.4	4.4	5.0	0.8

7. PCA of data used in models showing resettled and non-resettled households are comparable and seasonal differences are more prominent.



PCA results with the two most explanatory components as x and y axes. Colors signify seasons – Summer (red), Monsoon (green) and Winter (blue). Shapes signify resettled (square) and non-resettled (circle) households with almost entirely overlapping distribution in PCA loadings space. Variables used are all continuous and numeric categorical variables that were scaled prior to analyses.

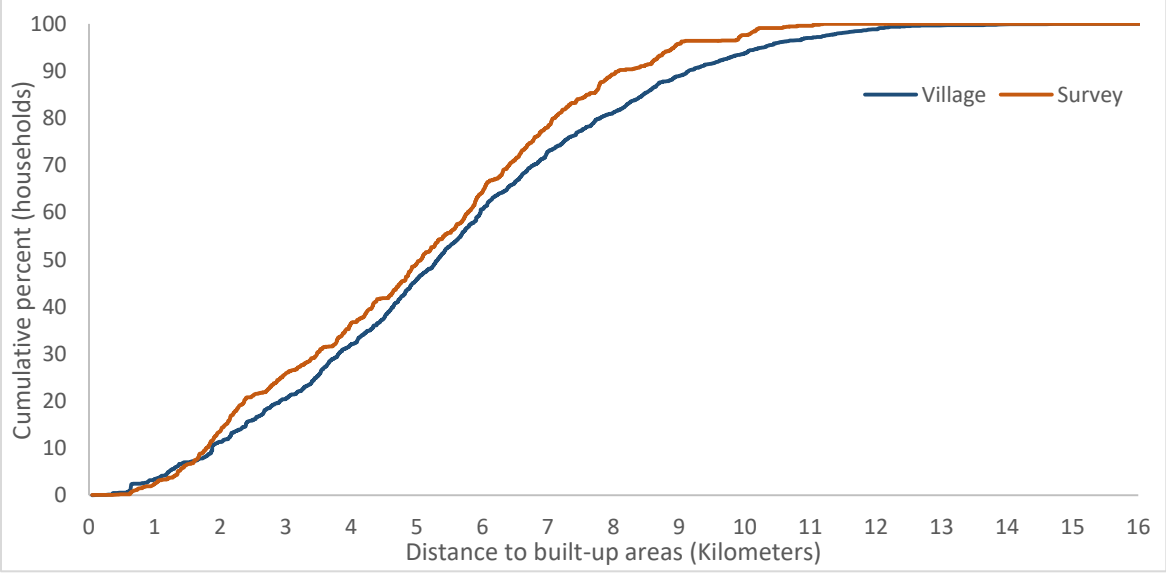
8. Local contextualizing of food access metrics used in this study

We use the FCS metric with standard thresholds for when households regularly use sugar and oil in our study (World Food Programme, 2008). Field manuals of the food access metrics used in our study stress the importance of key informant interviews and focus groups to understand how

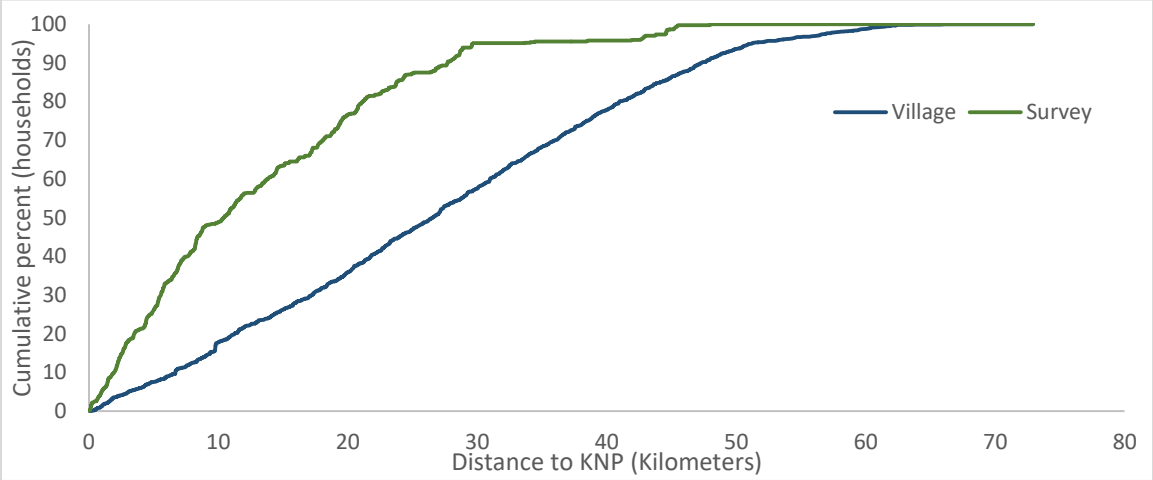
best to use the standardized metrics in a given context. Accordingly, we held key informant interviews and focus group discussions to generate a list of local names for foods as well as lesser known local foods. We also used the key informant interviews to understand the likely response to queries regarding mild to severe coping strategies. A query on begging as a coping strategy was removed from our survey instrument as begging is not a coping mechanism in this landscape (there are extremely few avenues to solicit food by begging unlike in large cities) and the query was judged as highly culturally insensitive. We conducted focus groups discussions with three village families from non-survey villages. Key informants ranged from villagers, drivers, managers and local people who lived in non-survey areas including a town family. Key informants were available and helpful throughout the duration of our field surveys but we gathered most local information during two pilot studies prior to these surveys.

9. Distance from KNP and forest cover

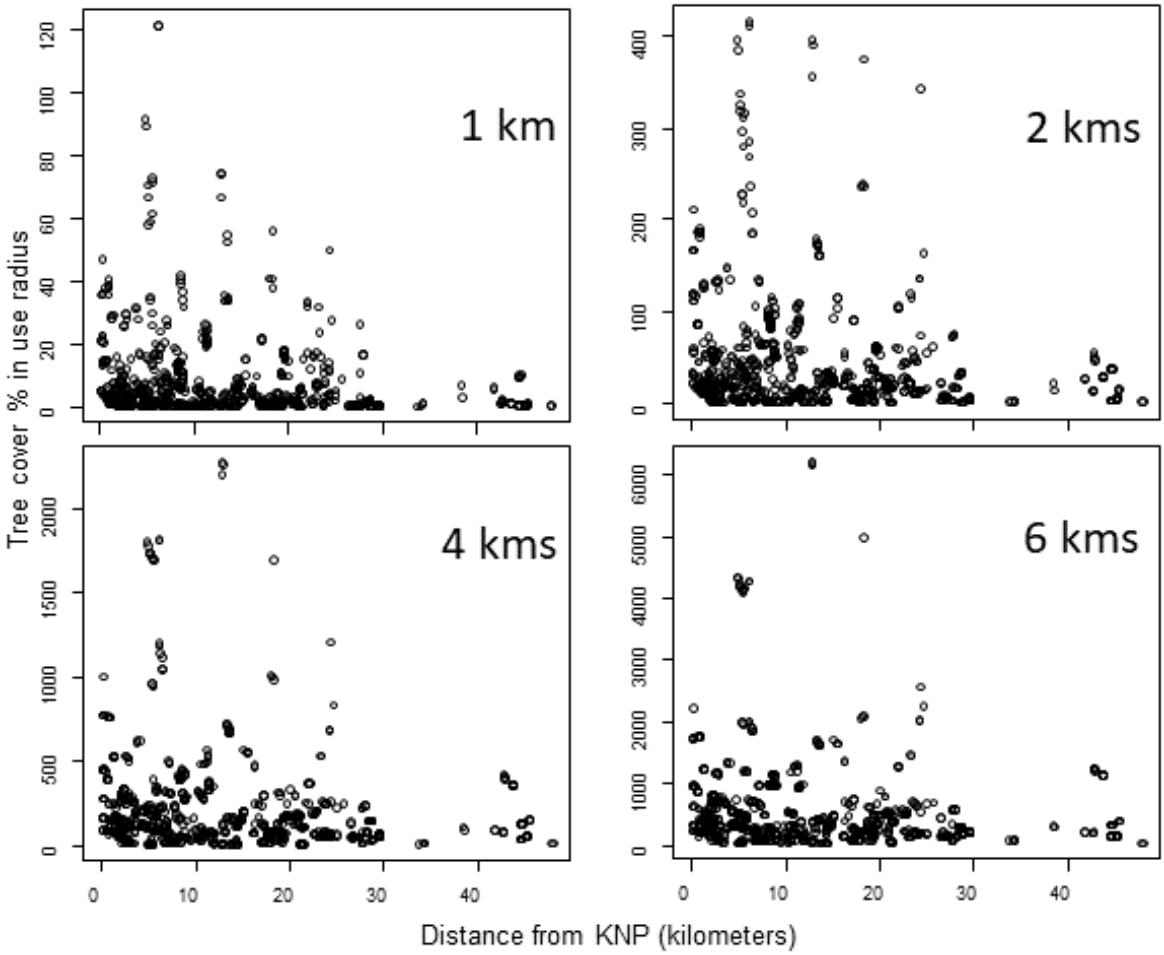
(a)



(b)


Cumulative percent (households)
Distance to KNP (Kilometers)
Village
Survey

(c)


1 km
2 kms
4 kms
6 kms
Tree cover % in use radius
Distance from KNP (kilometers)

Our survey data is representative of the larger KNP landscape human populations in terms of distance from built-up areas (a). We find that our sample is less representative of the larger landscape when considering distance to KNP perimeter (b) and we show that although tree cover decreases with increasing distance from KNP most households have similar mean tree cover in our sample (c).

10. Breakdown of households that accessed foods via market purchase, own production and foraging across all seasons (recorded as primary and secondary sources in FCSs measurements)

Summer Primary Sources (1332 households)

	Market Purchased	Own Production	Foraged	Total Households Reporting Access Of Food
Maize	78	122	0	202
Rice	443	877	0	1332
Wheat	429	94	0	571
Tuber	1214	39	0	1253
Peanuts	28	3	0	31
Pulses	1101	113	0	1216
Fish	334	16	0	350
Dry Fish	29	2	0	31
Red Meat	23	3	0	26
White Meat	143	30	0	174
Oil	1288	27	0	1315
Eggs	104	30	0	135
Milk In Tea	86	63	0	150
Dairy	15	44	0	60
Vegetables	1283	24	0	1308
Fruits	117	7	0	125
Wild Meat	2	0	0	2
Sweets	659	2	0	663

Summer Secondary Sources (1332 households)

	Market Purchased	Own Production	Foraged	Total Households Reporting Access Of Food
Maize	24	6	0	34
Rice	576	79	0	752
Wheat	88	21	0	123
Tuber	26	20	1	47
Peanuts	4	0	0	4
Pulses	56	39	0	99
Fish	2	1	0	3
Dry Fish	0	0	0	0
Red Meat	0	0	0	1
White Meat	0	1	0	3
Oil	16	9	0	28
Eggs	2	2	0	4
Milk In Tea	1	1	0	7
Dairy	0	1	0	1
Vegetables	17	27	0	45
Fruits	1	1	0	3
Wild Meat	0	0	0	0
Sweets	0	0	0	0

Monsoon Primary Sources (1066 households)

	Market Purchased	Own Production	Foraged	Total Households Reporting Access Of Food
Maize	25	43	0	71
Rice	633	428	0	1064
Wheat	323	34	0	357
Tuber	876	13	0	889
Peanuts	23	1	0	25
Pulses	901	70	0	973
Fish	217	19	0	238
Dry Fish	18	0	0	18
Red Meat	8	1	0	9
White Meat	169	19	0	190
Oil	993	10	0	1003

Eggs	54	1	0	55
Milk In Tea	15	49	0	66
Dairy	5	29	0	36
Vegetables	995	26	3	1025
Fruits	62	6	1	69
Wild Meat	1	0	2	3
Sweets	706	1	0	707

Monsoon Secondary Sources (1066 households)

	Market Purchased	**Own Production**	**Foraged**	**Total Households Reporting Access Of Food**
Maize	1	0	0	2
Rice	134	96	0	244
Wheat	2	2	0	6
Tuber	6	3	1	13
Peanuts	0	0	0	0
Pulses	11	4	0	15
Fish	2	0	0	3
Dry Fish	0	0	0	0
Red Meat	0	0	0	0
White Meat	0	0	0	1
Oil	4	0	0	10
Eggs	0	0	0	0
Milk In Tea	0	2	0	2
Dairy	0	0	0	1
Vegetables	11	12	7	36
Fruits	0	0	0	0
Wild Meat	0	0	0	0
Sweets	2	0	0	3

Winter Primary Sources (1121 households)

	Market Purchased	**Own Production**	**Foraged**	**Total Households Reporting Access Of Food**
Maize	28	181	0	210
Rice	279	841	0	1120

Wheat	426	41	0	467
Tuber	998	59	0	1060
Peanuts	52	1	0	53
Pulses	1003	46	0	1049
Fish	353	9	0	362
Dry Fish	25	2	0	27
Red Meat	7	1	0	10
White Meat	235	18	0	254
Oil	1083	29	0	1112
Eggs	77	15	0	92
Milk In Tea	18	36	0	54
Dairy	5	39	0	44
Vegetables	1019	96	0	1115
Fruits	36	15	0	53
Wild Meat	2	0	0	2
Sweets	462	0	0	462

Winter Secondary Sources (1121 households)

	Market Purchased	**Own Production**	**Foraged**	**Total Households Reporting Access Of Food**
Maize	6	2	0	8
Rice	338	58	0	399
Wheat	30	2	0	34
Tuber	34	18	0	54
Peanuts	0	0	0	0
Pulses	29	7	0	38
Fish	2	0	0	2
Dry Fish	1	0	0	1
Red Meat	0	0	0	2
White Meat	3	2	0	5
Oil	22	6	0	28
Eggs	1	2	0	3
Milk In Tea	2	2	0	4
Dairy	0	1	0	1
Vegetables	80	145	0	227
Fruits	3	1	0	4

Wild Meat	0	0	0	0
Sweets	2	0	0	4

11. Survey Instrument

सर्वे इंस्ट्रूमेंट

As mentioned in our consent statement we would be happy to explain the reasons for this study and you may choose to participate or opt out at any time during this interview. We are grateful for your helping us with this study. There are no benefits or payments for completing this interview with us.

जैसा कि हमारे सह्मति पत्र में लिखा है आपको हम ,इस अध्ययन के बारे में बताना चाहते हैं | आप अपनी इक्छा अनुसार इस सर्वे में भाग ले सकते हैं और सर्वे के दौरान किसी भी समय सर्वे में भाग लेने से मना कर सकते हैं |इस सर्वे में सहयोग के लिए हम आपके बहुत आभारी हैं|इस सर्वे में भाग लेने का आपको किसी भी प्रकार का भुगतान या लाभ नहीं मिलेगा|

Introductory questions:

What is your name?
आपका नाम क्या है?
When did this family come to this area?
आपका परिवार इस इलाके में कब आया?
This village?
इस गाँव में?
From where and why? (Auto Recorded)
कहाँ से और क्यों?
How many people live in this house?
इस घर में कितने लोग रहते है?

Adults: Children (below 18 years of age):

वयस्क बच्चे (18 से कम आयु के)

Did other households move here with you?
क्या आपके परिवार के साथ कुछ और परिवार भी आपके साथ आये? कितने परिवार आये थे?

How many?
कितने परिवार आए थे?

Do you have relatives (blood relations) in the area?
क्या इस इलाके में आपका कोई रिश्तेदार (सगे सबंधि) भी है?

How many relatives?
कितने रिश्तेदार है?
What is the ethnicity of people in the house? (SC/OBC/ST and name of caste/ tribe if applicable)

इस घर के लोगों की जाति क्या है? (अनुसूचित जाति/पिछड़ी जाति और जाति का नाम/जनजाति अगर लागू हो)
Income Details

Source of Income	Primary Source	Secondary Source
Farming/Agriculture		
Livestock (cattle)		
Livestock (Poultry)		
Seasonal Labour		
Labour (based on work availability)		
Others (Specify)		

आय का विवरण

आय का स्रोत	प्राथमिक स्रोत	द्वितीय स्रोत
खेती बाड़ी/ कृषि		
मवेशी पालन		
मुर्गीपालन		
श्रम (एक महीने से ज्यादा या लम्बे तौर पर)		
श्रम (काम की उपलब्धता के आधार पर)		
अन्य (उल्लेख कीजिये)		

We have been talking to the official who handles the receipts for Tendu trade in the village and will be using some information on Tendu trade in this region
हम उन अधिकारियों से बात कर रहे है जो तेंदू व्यापार से संबंधित रसीदे सँभालते है और हम उनसे मिली जानकारी इस्तेमाल करेंगे?
Is there any additional income from Tendu leaf collection in your household?
क्या आपका परिवार तेंदू पत्ता इकठ्ठा करके अलग से कमाई करता है ?

Who collects Tendu leaves and when? – time of day as well as season
कौन और कब तेंदू पत्ता इकठा करता है? – दिन में किस समय और किस मौसम में
How many heads of livestock do you own? (Cows / Buffalo / Ox / Goats / Chicken / Pig)
आपके पास खुद के कितने पशु है? (गाय/ भेंस / बैल/ बकरी/ मुर्गी/ सूअर)

Do you have LPG as fuel for cooking? (Yes or No)

Cost of LPG	
How far you travel to get LPG?	
What is the average time duration to get LPG?	

क्या आपके खाना पकाने के लिए घरेलू गैस को इस्तेमाल करते है? (हाँ या नहीं)

कीमत	
आपको कितना दूर जाना पड़ता है LPG लेने?	
औसतन कितना समय लगता है आपको एलपीजी मिलने में?	

Do you have Firewood as fuel for cooking? (Yes or No)

Cost of Firewood	
How far you travel to get Firewood?	
What is the average time taken to get Firewood?	

क्या आप खाना जलौनी लकड़ी पर पकाते है? (हाँ या नहीं)

जलौनी लकड़ी की कीमत	
जलौनी लकड़ी को इकठ्ठा करने के लिए कितना दूर जाना पड़ता है?	
जलौनी लकड़ी को इकठ्ठा करने के लिए कितना औसत समय लगता है?	

Do you enjoy foods cooked on kerosene?

Cost of kerosene at PDS shop	
Cost of kerosene from market	
How far you travel to get kerosene?	
What is the average time taken to get kerosene?	

क्या आप खाना पकाने के लिए मिट्टी तेल का इस्तेमाल करते है? (हाँ या नहीं)

सरकारी दुकान पर मिट्टी तेल की कीमत	
बाज़ार में मिट्टी तेल की कीमत	
मिट्टी तेल खरीदने के लिए कितना दूर जाना पड़ता है?	
मिट्टी तेल खरीदने के लिए के लिए कितना औसत समय लगता है?	

Do you enjoy foods cooked on wood fires?
क्या आप लकड़ी पर खाना बनाना पसंद करते है?

Are there particular foods that you prefer to cook on wood fires?
क्या कुछ विशेष भोजन है जो आप लकड़ी पर बनाना पसंद करते है?

FCS: example data sheet from field manual

एफसीएस :फील्ड मैनुअल से उदाहरण डेटा शीट

*I would like to ask you about all the different foods that your household members have eaten in the **last 7 days**. Could you please tell me **how many days** in the past week your household has eaten the following foods?*
(for each food, ask what the primary source of each food item eaten that week was, as well as the second main source of food, if any)

Food item	DAYS eaten in past week (0-7 days)	Sources of food (see codes below)	
		primary	secondary
#.1 – Maize			
#.2 – Rice			
#.3 – Bread/wheat			
#.4 – Tubers			
#.5 – Groundnuts & Pulses			
#.6 – Fish (eaten as a main food)			
#.7 – Fish powder (used for flavor only)			
#.8 – Red meat (sheep/goat/beef)			
#.9 – White meat (poultry)			
#.10 – Vegetable oil, fats			
#.11 – Eggs			
#.12 – Milk and dairy products (main food)			
#.13 – Milk in tea in small amounts			
#.14 – Vegetables (including leaves)			
#.15 – Fruits			
#.16 – Sweets, sugar			

Food source codes:

Purchase =1	Own production =2	Traded goods/services, barter =3
Borrowed = 4	Received as gift= 5	Food aid =6
Other (specify) =7		

मैं आपसे उन सभी अलग अलग खाद्य पदार्थो के बारे में पूछना चाहता हूँ ने सदस्यों के घर आपके जिन्हें , प्राथमिक उसके था गया खाया सप्ताह पिछले जो भोजन ,लिए के भोजन प्रत्येक)| है खाया में दिनों 7 पिछले माध्यमिक तथा स्रोत स्रोत के बारे में पूछे

भोज्य पदार्थ	पिछले सप्ताह 7 गया खाया में दिनों पदार्थ भोज्य	भोजन के स्रोत नीचे) कोड्स देखे(		चीज
		प्राथमिक स्रोत	माध्यमिक स्रोत	
1. मक्का				
2. चावल				
3. रोटी/ गेहूँ				
4. कंदमूल (आलू/ कान्धा)				
5. मूंगफली				
6. दालें				
7. मछली (मुख्य भोजन के रूप में)				
8. सूखी मछली				

9. लाल मांस (भेड़, बकरी, गाय)				
10. सफ़ेद मांस (मुर्गी पालन)				
11. वनस्पति तेल, घी, डालडा				
12. अंडे				
13. दूध और डेयरी उत्पादों (भोजन मुख्य)/ पनीर/ दही				
14. दूध की चाय कम मात्रा में				
15. सब्जियाँ				
16. फल				
17. जंगली मीट				
18. मिठाइयाँ/ चीनी				

खाद्य स्रोत कोड

खरीद फ़रोख्त	1
स्वयं उत्पादन	2
कारोबार के सामान	3
चीजों का आदान प्रदान, सेवाएं/ उधार	4
उपहार के रूप में प्राप्त किया	5
खाद्य सहायता	6

What did you grow in your fields this season?
इस मौसम में आपने अपने खेत में क्या उगाया?

What did you do with the field production?

खेतों की उपज का आप क्या करते है?
बिक्री % भण्डारण % उपभोग करना %

Sale % Storage % Consume%

What did you consume from your garden this season?
इस मौसम में आपने अपने बाड़े से उगाये किस चीज़ का आपने इस्तेमाल किया?

Assets: Do you have one or more of the following – (please note how many of each)
सम्पति: क्या आपके पास एक और एक से अधिक दी गयी सम्पति है? (संख्या लिखे)

Radio/ Transistor रेडियो/ ट्रांसिस्टर	Television टेलिविज़न	Computer/Laptop कंप्यूटर/लैपटॉप		Telephone/Mobile Phone टेलीफोन/मोबाइल			Bicycle साइकिल	Scooter/ Motorcycle/ Moped स्कूटर/मोटर-साइकिल/ मोपेड	Car/ Jeep/ Van कार/ जीप/ वैन
		With Internet इन्टरनेट के साथ	Without Internet इन्टरनेट के बिना	Landline only केवल लैंडलाइन	Mobile with Internet मोबाइल (इन्टरनेट के साथ)	Mobile without Internet मोबाइल (इन्टरनेट के बगैर)			

Type of House:

- Kcchha
- Pukka
- Half kccha half pukka

घर के प्रकार:

- कच्चा
- पक्का
- आधा कच्चा आधा पक्का

CSI: We would now like to talk a bit about how you manage during hard times (seasonal fluctuation of availability of foods or incomes) **Consumption Coping Strategy Responses (CSI)**

अब हम इस बारे में आपसे बात करेंगे कि मुश्किल दौर में यानी (मौसम के हिसाब से) खाने की चीजों की मौजूदगी या कमाई में उतार-चढाव के बारे में जानना चाहेंगे?

Frequency - Number of days out of
Behaviors: the past seven:

आवृत्ति बाहरजानकारी से संख्या की दिनों -
व्यवहार: पिछले सात :

In the past 7 days, if there have been times when you did not have enough food or money to buy food, how many days has your household had to:
पिछले सात दिनों में, क्या कभी ऐसा समय आया जब आपके पास पर्याप्त भोजन या भोजन खरीदने के लिए पर्याप्त पैसे नहीं थे, आपको कितने दिन इस तरह से गुजारने पड़े:
(इस्तेमाल करे 7-0 दिनों की संख्या के लिए ,NA इस्तेमाल करे लागू नहीं के लिए)
(Use numbers 0 – 7 to answer number of days; use NA for not applicable)
a. Rely on less preferred and less expensive foods?
क्या पिछले सात दिनों में आपको कम पसंद और सस्ते भोजन पर निर्भर होना पड़ा? (0-7 दिन)

~~Borrow food, or rely on help from a friend or relative?~~ *(removed as this practice is very common and not representative of any hardship; in hardship people are more likely to associate such a behavior with begging for food – see below.)*

Purchase food on credit? Or food for work? *(local practice of borrowing food / credit for services)*

पिछले सात दिनों में, क्या आपको खाने की चीज़े उधार लेनी पड़ी या खाने की चीजों के बदले काम करना पड़ा? (0-7 दिन)

Gather wild food, hunt, or harvest immature crops?
पिछले सात दिनों में, क्या आप जंगल से भोजन इकट्ठा किया या शिकार किया या कच्ची फसलों को काटा? (0-7 दिन)

Consume seed stock held for next season?
पिछले सात दिनों में, आने वाले मौसम के लिए रखे गए बीज का भंडार को इस्तेमाल किया? (0-7 दिन)

Send household members to eat elsewhere?
पिछले सात दिनों में, परिवार के सदस्यों को कहीं और खाने के लिए भेजा? (0-7 दिन)

~~Send household members to beg?~~*(removed as this is culturally insensitive to a point where no one will admit to it.)*

Limit portion size at mealtimes?
पिछले सात दिनों में, हिस्से में आने वाली मात्रा को कम किया ?(0-7 दिन)

Restrict consumption by adults in order for small children to eat?
पिछले सात दिनों में, वयस्कों के भोजन को सीमित किया ताकि छोटे बच्चों को खाना खिला पाए? (0-7 दिन)

Feed working members of HH at the expense of nonworking members? (0-7 दिन)

पिछले सात दिनों में, काम करने वाले सदस्यों को काम न करने वाले सदस्यों के खर्चे से खाना खिलाया?

Reduce number of meals eaten in a day?
पिछले सात दिनों में, पूरे दिन में भोजन की संख्या कम की? (0-7 दिन)

Skip entire days without eating?

पिछले सात दिनों में, पूरा दिन बिना खाना खाए निकाले? (0-7 दिन)

Do you send your children to school for mid-day meal?
पिछले सात दिनों में, क्या बच्चों को आप मिड डे मील (भोजन) के लिए स्कूल भेजा? (0-7 दिन)

HHS: Now we would like to talk a bit about how you manage the household when very tough times occur.
हाउसहोल्ड सर्वे: अब हम आपसे इस बात पर चर्चा करेंगे कि आप अपना घर बहुत कठिन समय में कैसे चलाते है |

Q1 In the past [4 weeks/30 days], was there ever no food to eat of any kind in your house because of lack of resources to get food?
Q1- पिछले[4 हफ्ते/30 दिनों में]क्या ऐसा भी हुआ है की खाना पाने की सुविधाओं के अभाव में आपके घर में बिलकुल भी खाना नहीं था?
= No (Skip to Q2)
नहीं(प्रश्न 22 पर जाएँ)
= Yes
हाँ
|___|

Q1a How often did this happen in the past [4 weeks/30 days]?
= Rarely (1–2 times)
= Sometimes (3–10 times)
= Often (more than 10 times)
|___|
Q1a- पिछले[4 हफ़्तों/30 दिनों] में ऐसा कितनी बार हुआ है?
बहुत कम(1-2 बार)
कभी-कभी(3-10 बार)
आमतौर पर(10 से ज्यादा बार)

Q2 In the past [4 weeks/30 days], did you or any household member go to sleep at night hungry because there was not enough food?
= No (Skip to Q3)
= Yes
|___|

Q2- पिछले[4 हफ़्तों/30 दिनों] खाना न होंबे की वजह से आप या आपके परिवार का कोई सदस्य रात में भूखा सोया है?
नहीं(प्रश्न 3 पर जाएँ)
हाँ

Q2a How often did this happen in the past [4 weeks/30 days]?
= Rarely (1–2 times)
= Sometimes (3–10 times)
= Often (more than10 times)
|___|
Q2a- पिछले[4 हफ्ते/30 दिनों] में ऐसा कितनी बार हुआ है?
बहुत कम(1-2 बार)
कभी-कभी(3-10 बार)
आमतौर पर(10 से ज्यादा बार)

Q3 In the past [4 weeks/30 days], did you or any household member go a whole day and night without eating anything at all because there was not enough food?
= No (Skip to the next section)
= Yes
|___|
Q3- पिछले[4 हफ़्तों/30 दिनों] में क्या आप या आपके घर का कोई सदस्य खाना न होने की वजह से पूरा दिन और पूरी रात बिना खाना खाए रहा है?
नहीं(अगले सेक्शन पर जाएँ)
हाँ

Q3a How often did this happen in the past [4 weeks/30 days]?
= Rarely (1–2 times)
= Sometimes (3–10 times)
= Often (more than 10 times)
|___|
Q3a- ऐसा कितनी बार हुआ है?
बहुत कम(1-2 बार)
कभी-कभी(3-10 बार)
आमतौर पर(10 से ज्यादा बार)

Health and water use (this section added to better capture utilization of foods and address sanitation facilities)
स्वास्थय और पानी का इस्तेमाल

Question	Codes	Source
Has any child (below 5 years old) in this household had diarrhea in the last 2 weeks?	1= Yes 2= No	DHS DHS

क्या इस घर में किसी बच्चे(5 साल से कम) को पिछले 2 हफ़्तों में डाईरिया हुआ है?	1=हाँ 2=नहीं	
How many children have had diarrhea in the last 2 weeks? पिछले 2 हफ़्तों कितने बच्चों को डाईरिया हुआ था?	[number of children with diarrhea] [डाईरिया से पीड़ित बच्चों की संख्या]	
How many days in the last 2 weeks did the child / children have diarrhea? पिछले 2 हफ़्तों में कितने दिनों तक बच्चा/बच्चे डाईरिया से पीड़ित थे?		DHS
Has any child (below 5 years old) had a fever in the last 2 weeks? क्या पिछले 2 हफ़्तों में किसी बच्चे(5 साल से कम) को बुखार हुआ था?	1= Yes 2= No 1= हाँ 2= नहीं	
How many children have had fever in the last 2 weeks? पिछले 2 हफ़्तों में कितने बच्चों को बुखार हुआ था?	[number of children with fever] [बुखार से पीड़ित बच्चों की संख्या]	
How many days in the last 2 weeks did the child / children have fever? पिछले 2 हफ़्तों में कितने दिनों तक बच्चा/बच्चे बुखार से पीड़ित थे?		

What toilet facilities do you use as a household? (Open defecation in fields / community toilet / household toilet)

आपका घर किस तरह की शौचालय इस्तेमाल करता है?(खुले में शौंच/सामुदायिक शौचालय/घर का शौचालय)

(If household toilet) What kind of toilet would you consider this – dry long drop / water flushed? What is the source for water for this house?

(अगर घर का शौचालय) आप इसको किस प्रकार का शौचालय कहेंगे-कम्पोस्ट शौचालय/फ्लश शौचालय? Is it within the premises?

क्या शौचालय घर की चारदीवारी में ही है?

(If source of water is not in premises) Who gets water for this household every day?

(अगर पानी का स्त्रोत घर में नहीं है तो) इस घर के लिए रोजाना पानी कौन लेकर आता है?

How much time does it take to get to the source of water from this house?

जहाँ से आप पानी लाते है वहां से आपको घर आने में कितना समय लगता है?

How far would you say the distance to source is?

जहाँ से आप पानी लाते है वो जगह आपके घर से कितनी दूर है?

Do you wash your hands with soap? क्या आप अपने हाथ साबुन से धुलते हैं?	1=Yes 2= No	Basic TL WASH survey
Do you wash your hands with ash? क्या आप अपने हाथ राख़ से धुलते हैं?	1=हाँ 2=नहीं	
Do you wash your hands with mud? क्या आप अपने हाथ मिट्टी से धुलते है?	1=हाँ 2=नहीं	
How many times do you wash your hands? आप कितनी बार हाथ धुलते हैं?	*[times per day]* *[दिन में कितनी बार]*	Besik TL WASH survey
For which of the following is hand washing appropriate? इनमे से किस के लिए हाथ धुलना सही है?	1= Before every meal 2= After every meal 3= Before using the toilet 4= After using the toilet 5= Before cooking 6= After cooking 7= After working 8= Before going to sleep 9=Other (specify) 1=खाने से पहले 2=खाने के बाद 3=शौचालय जाने से पहले 4=शौचालय जाने के बाद 5=खाना बनाने से पहले 6=खाना बनाने के बाद 7=काम ख़त्म करने के बाद 8=सोने से पहले 9=अन्य (उल्लेख कीजिये)	Besik TL WASH survey
Why do you think hand washing is appropriate? आपको क्यों लगता है कि हाथ धुलना ज़रूरी है?	1= Reduce germs/ disease 2= Looks nicer 3= Someone told me it was nice 4= I do not know 5= Other 1=कीटाणु/बीमारियाँ कम करता है 2=हाथ अच्छे दिखते हैं 3=किसी ने मुझे बताया था कि ये अच्छा होता है 4=पता नहीं 5=अन्य (उल्लेख कीजिये)	Besik TL WASH survey

Forest use
जंगल का प्रयोग
Are there foods that you eat from the forest?
1= Honey
2= Mahua
3= Mushroom
4= Others
क्या आप जंगल से प्राप्त खाना भी खाते है?(शहेद,महुआ,मशरूम-फोकस ग्रुप की प्रतिक्रिया)
1= शहद
2= महुआ
3= पिरही
4= अन्य (उल्लेख कीजिये)

Are there medicines from the forest that you use? (haldu bark as an example)
क्या आप जंगल से प्राप्त दवाइयां भी इस्तेमाल करते हैं?(जैसे हल्दू बर्क)
Are forests in this region useful for you in any way other than food or medicines? (fuelwood and mahua as examples… but also ask about others)
क्या इस इलाके के जंगल आपके लिए खाने और दवाई के अलावा किसी अन्य रूप से उपयोगी हैं?
Are there religious places and cultural ties that your family has with the forests? (Bhoramdeo temple, Tribal Art and inspirations)
क्या आपके परिवार का जंगलों में कोई धार्मिक स्थान या संस्कृतिक सम्बन्ध है?(भोरमदेव मंदिर,आदिवासी कला और प्रेरणा)

Are you able to access these things within forests in the region?
क्या आप इस इलाके के जंगलों से यह वस्तुएं प्राप्त कर लेते हैं?

Human-wildlife Conflict (note - there are 2 questions for the interviewer only)
मानव-जंगल का संघर्ष(नोट-2 प्रश्न सिर्फ एनुमेरेटर के लिए हैं)
We are now going to ask you a bit about how the animals and people here live together.
अब हम आपसे यह पूंछने जा रहे हैं कि जानवर और इंसान एक साथ कैसे रहते हैं?

1) Have your crops been raided this season?
   इस मौसम में आपकी फसलें उग चुकी हैं?
2) What percentage of the crop was damaged?
   फसल के कितना प्रतिशत भाग को नुक्सान हुआ है?

0-20% under 50% above 80% ALL of the standing crop

- 0-20%
- 50% से कम
- 80% से ज्यादा
- पूरी फसल

3) What animal do you think damaged the crop?
आपके हिसाब से किस जानवर ने फसल को नुक्सान पहुँचाया होगा?

4) Why do you think it is that animal?
आपको ऐसा क्यों लगता है कि इसी जानवर ने नुक्सान किया होगा?

How many of your livestock were killed by large carnivores in the last 1 year (This May to last May)?
पिछले 1 साल में आपके कितने जानवर बड़े मांसाहारियों द्वारा मार दिए गए हैं?(इस मई से पिछली मई तक)

For each animal that was killed by large carnivores are you willing to show us the place you found the carcass and the place where you think the animal was attacked? (as you may know that tigers and leopards often drag their prey and hide it)

- If Yes (take 2 GPS points)
- If No (End the interview)

अब हम आपसे उन जगहों के बारे में जानना चाहेंगे जहाँ जानवर बड़े मांसाहारी जानवरों के द्वारा मारे दिए गए| (जैसा की आप जानते है की चीता और तेंदुआ आमतौर पर अपने शिकार को घसीट कर छुपा देते है)

- अगर हाँ (2 जीपीएस पॉइंट लीजिये)
- अगर नहीं (तो सर्वे थैंक यू बोल कर ख़तम कर दीजिये)

Show us where you found the carcass (consumption site) for first GPS point.
हमें बताइए कि आपको अवशेष कहा मिले थे(उपभोग का स्थान)

What evidence helped you determine that the animal was attacked here? (for second GPS point)
किस सबूत से आपको लगा की जानवर पर हमला यहाँ पर हुआ था? (दुसरे पोइंट पर ये सवाल पूछे)

For the interviewer only: Based on their evidence, how confident are you that they know where the kill site was? Confident or not confident?

उनके सबूतों की बिनाह पर, आपको कितना विश्वास है कि उन्हें हत्या की जगह के बारे में पता था?विश्वास है या विश्वास नहीं है?

Which predator (tiger, leopard, dhole) do you think killed the livestock? What evidence helped you determine this?

आपके हिसाब से किस हिंसक (चीता,तेंदुआ,ढोल) ने जानवर की हत्या करी थी?किस सबूत ने यह पहचानने में आपकी मदद करी?

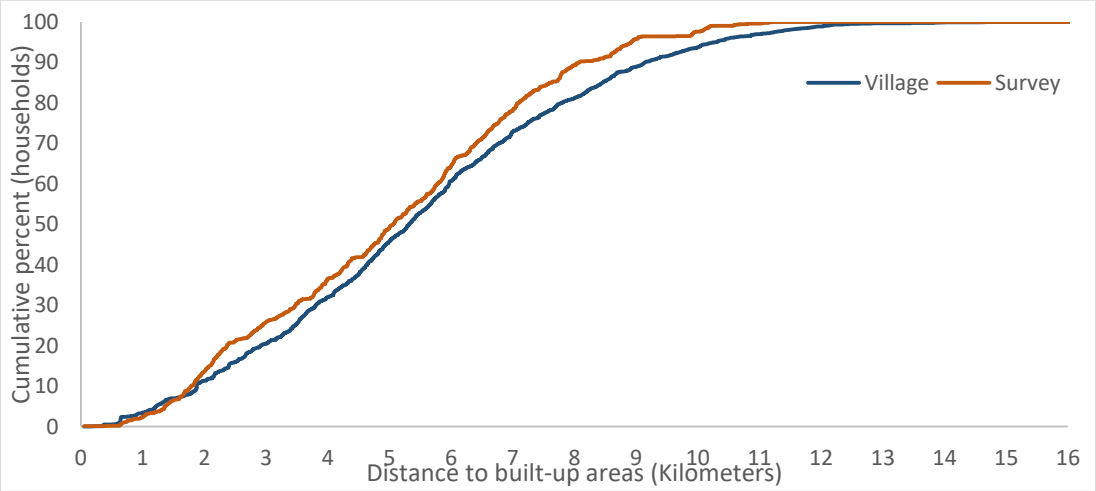
For the interviewer only: Based on their evidence, how confident are you that they accurately identified the predator? Confident or not confident?
उनके सबूतों के हिसाब से, आपको कितना विश्वास है कि उन्होंने सही तरह से दरिन्दे को पहचान लिया था?विश्वास है या विश्वास नहीं है?

Thank you. Please let us know if you would be interested to hear what this study finds out in a year or so – we will be happy to share a summary with you.
धन्यवाद. कृपया हमें बताएं कि क्या आप यह जान्ने में रूचि रखते हैं कि इस शोध का एक साल के बाद क्या परिणाम होगा-हम` आपको इसकी जानकारी देकर खुसी महसूस करेंगें.
12.

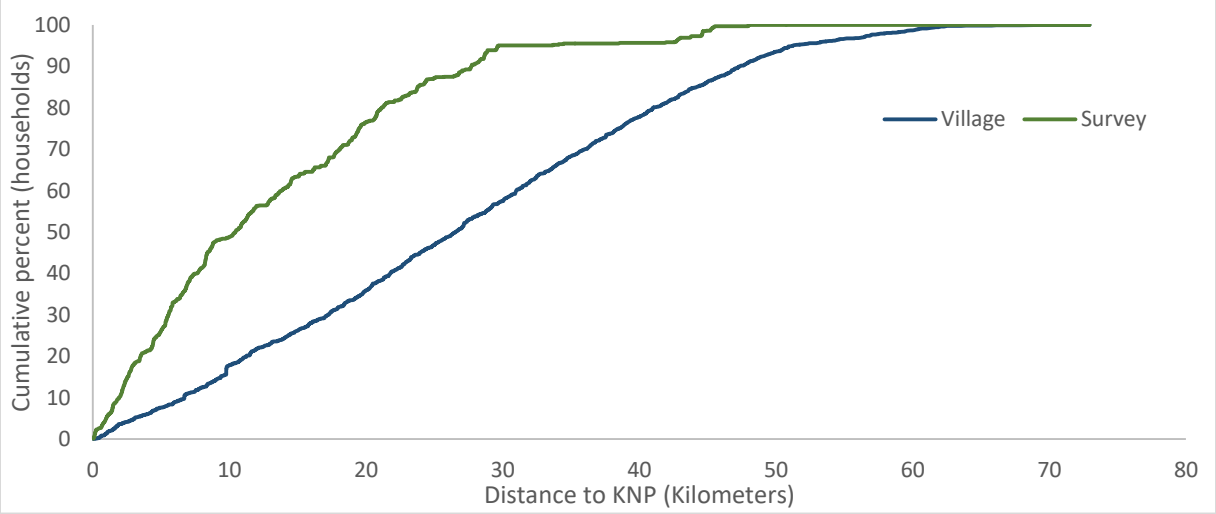
APPENDIX 2 – SUPPLEMENTARY MATERIALS FOR CHAPTER 3

1. Representability of our survey locations across the landscape:

(a)



(b)



(c)

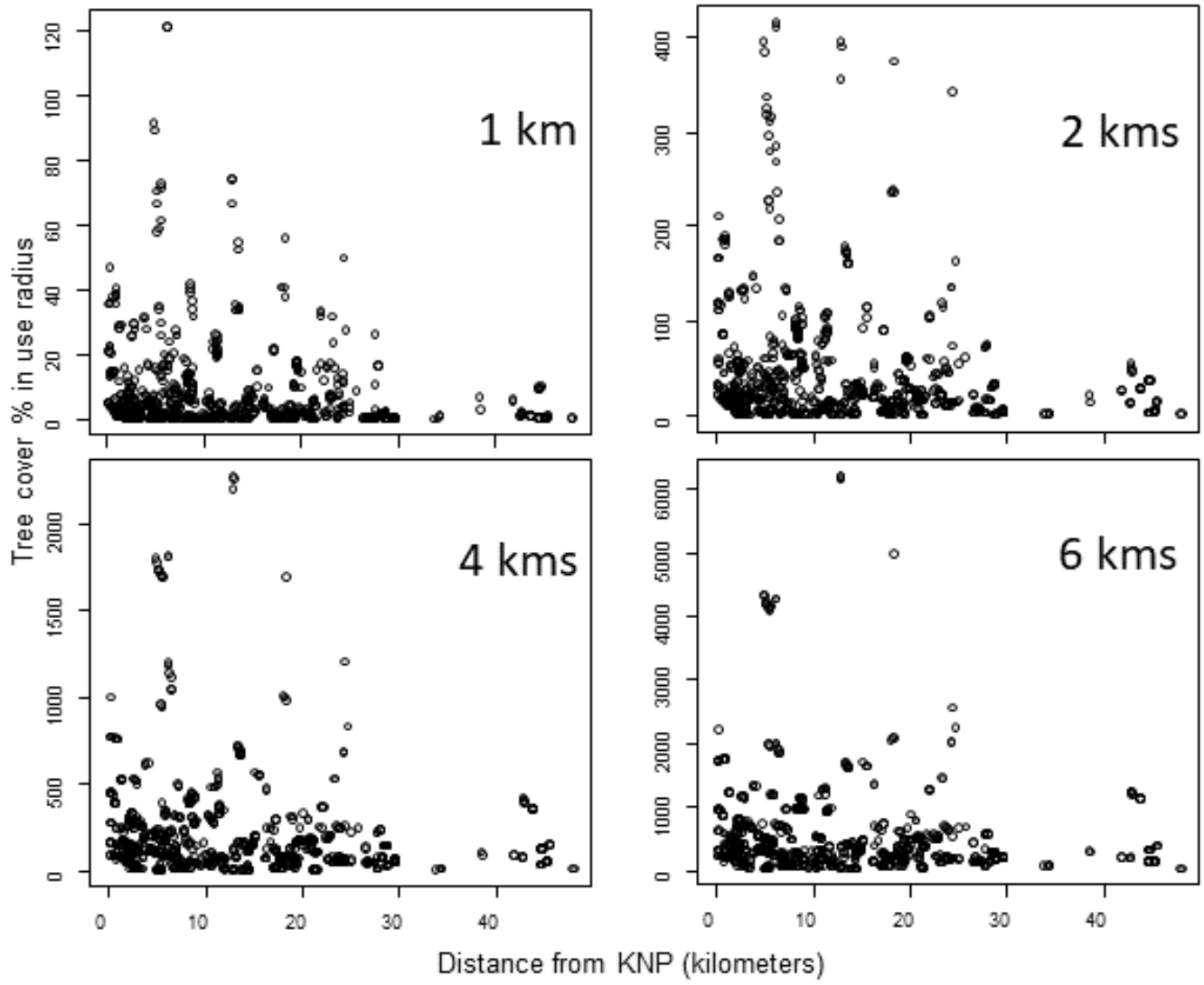


Figure 1: Our survey data is representative of the larger KNP landscape human populations in terms of distance from built-up areas (a). We find that our sample is less representative of the larger landscape when considering distance to KNP perimeter (b) and we show that although tree cover decreases with increasing distance from KNP, most households have similar mean tree cover in our sample (c).

2. Indicators of capitals as we measured them in our study

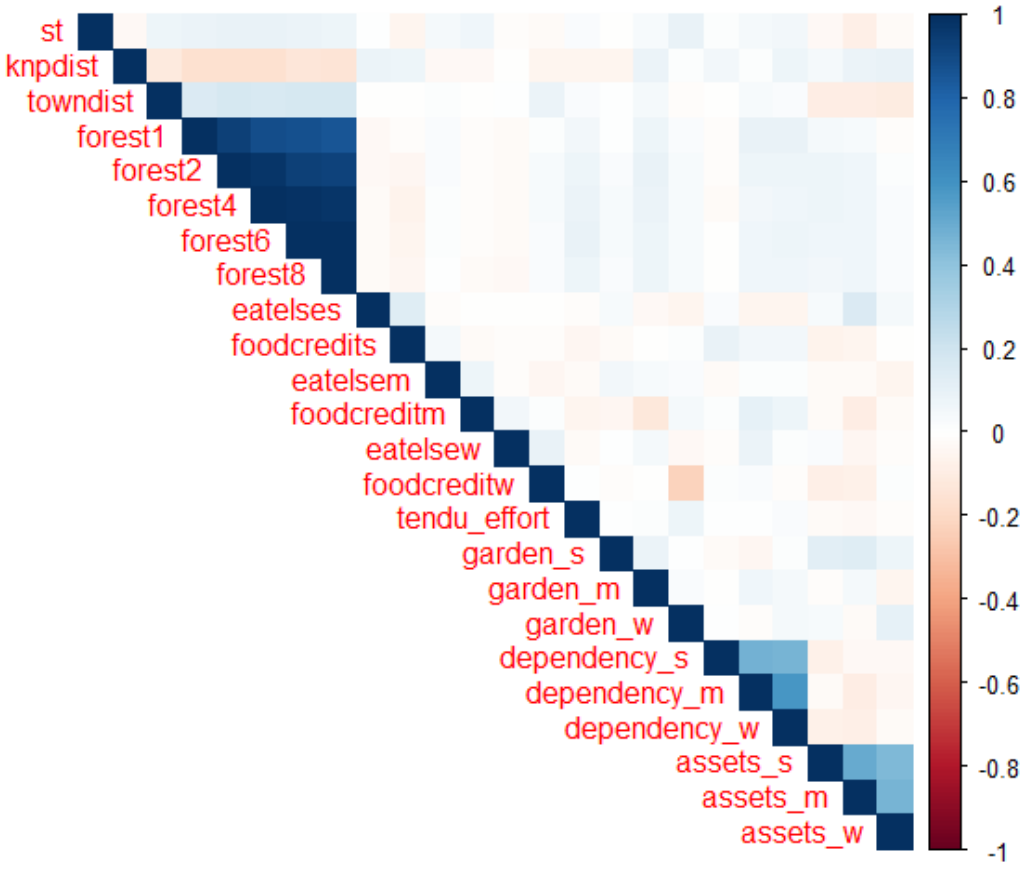
Table 1: Means and standard deviations of each variable we used to analyze household FCSs. Additional notes clarify how we measured a particular metric and relevant references.

Variable	Mean	Std. Dev	Units	Source
Natural Capital				
Tendu extraction effort	4.8	21.4	Household members who collect *tendu* * number of days *tendu* collected/season	Survey
Tree cover / household	7.7; 42.7; 217.2; 550.4; 1014.5	13; 61.1; 288; 698.4; 1225.4	Tree cover estimation within radius (1;2;4;6; and 8 kms) / total households in village	(M. C. C. Hansen et al., 2013) and census
Distance to KNP	13.07	10.68	Euclidean distance from survey point to nearest built-up area in kilometers.	QGIS using nnjoin
Natural sources of Income	Categorical		NTFP income reported as yes / no	Survey

Social Capital				
Send family members to eat elsewhere	0.02	0.2	Frequency of 1 to 7 days within a week	Survey
Food in lieu of work / credit	0.48	1.04	Frequency of 1 to 7 days within a week	Survey
Financial Capital				
Income sources	Categorical		Agriculture, Financial (jobs), Labor – reported in semi-structured interviews	Survey
Assets	5.5	4.64	Number of commercial household goods described in Indian government census (television, motorbike, mobile phone etc.) – higher weights for more costly and less prevalent assets	Survey (Kishor & Parasuraman, 1998)
Distance to town	5.07	2.41	Euclidean distance from survey point to nearest built-up area in kilometers. Built-up areas are defined as areas containing a	(ISCGM, 2007) and QGIS

			concentration of building and other structures, see – ISCGM, 2007	using nnjoin
Other variables (RE = random effect; FE = fixed effect)				
Tehsil (administrative unit) (RE)	Categorical		Name of *tehsil*	Survey and GIS
Within KNP Buffer (RE)	Categorical		Yes / no	Survey and GIS
Scheduled tribe (RE)	Categorical		Yes / no	Survey
Resettled (RE)	Categorical		Yes / no – data from forest department validated in our surveys	Surveys
Dependency ratio (FE)	0.6	0.55	Children / adults in household	Survey
Home garden diversity (FE)	0.38	0.61	1 point for each item type (e.g. no kitchen garden = 0, eggplant =1, eggplant and spinach = 2)	Survey
Tar (Pukka) road (FE)	Categorical		present / absent at village	Google Earth

3. Correlation matrix of all variables used in models: highly correlated variables were never included in the same model – we use one measure of forest availability at a time and similarly seasonal information according to the seasonal model.



4. FCSs change seasonally but do not show stark geographic trends, especially in regards to distance from KNP.

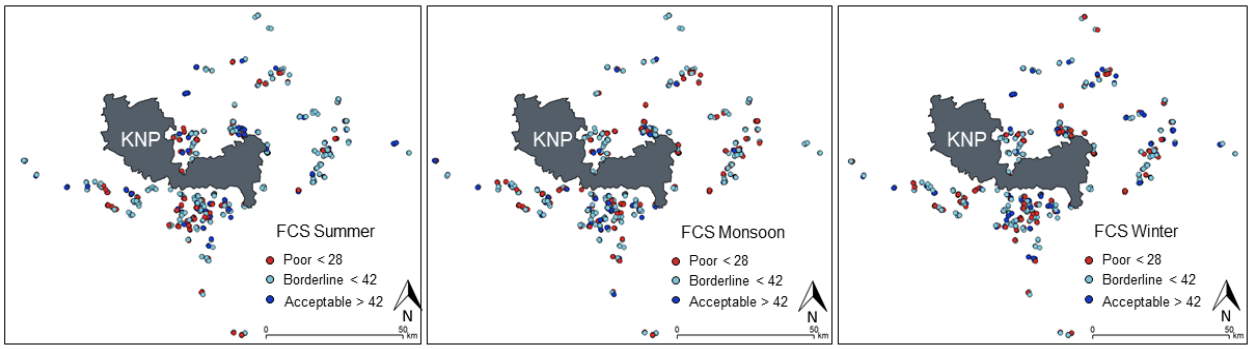


Figure 2: Households closer to and further away from KNP have varying FCS scores and no clear geographic trends visible.

5. Categorized households according to income profiles.

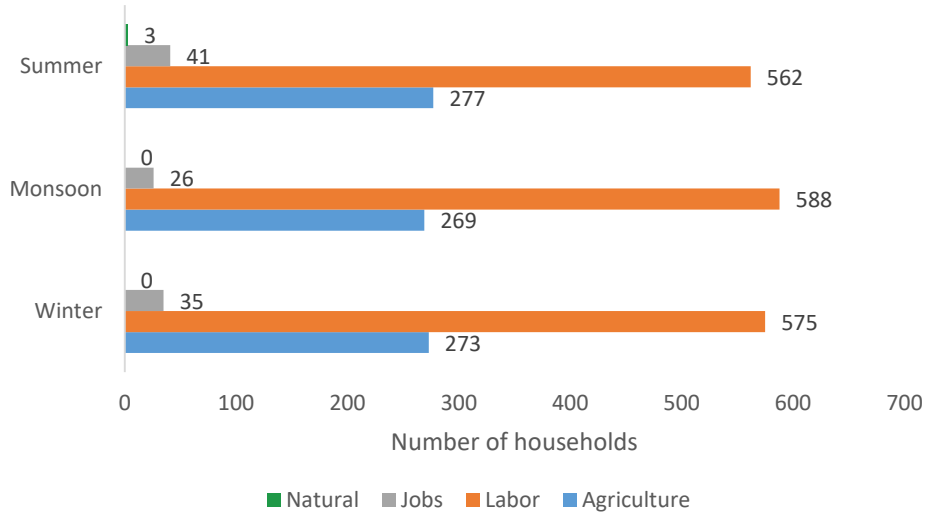


Figure 3: Four income profiles prevalent in the KNP landscape – agricultural (including incomes from cattle and poultry but not labor), labor (labor only or in addition to incomes from

agriculture / cattle / poultry), jobs (job salary only or in addition to any other income), and natural (households that reported *tendu* trade incomes in addition other incomes).

6. Regression tree results for each season – partitioning capital indicators associated with household FCSs

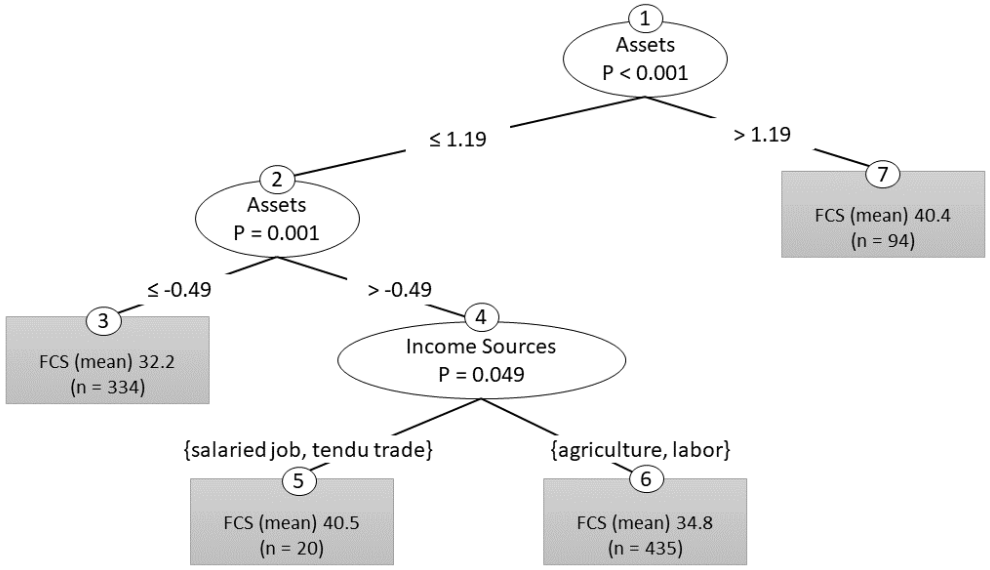


Figure 4: Regression tree on modelled variables in summer show the importance of assets and income sources. All continuous variables used in analyses were standardized and terminal nodes report mean FCSs for the subset with number of households (n).

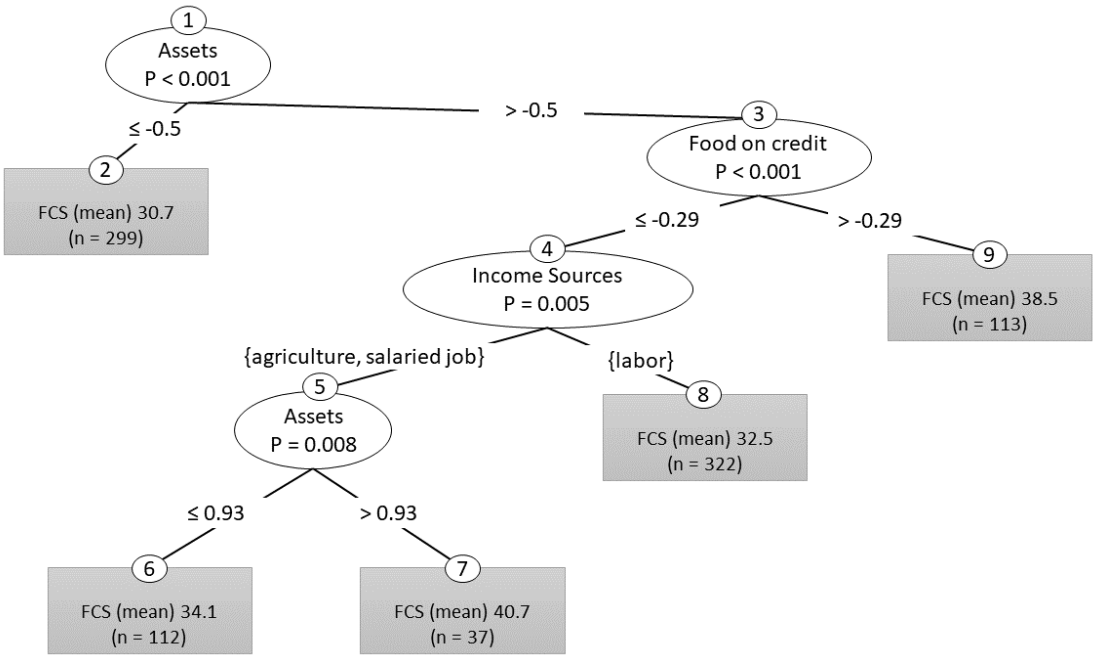


Figure 5: Monsoon survey data showing modelled variables in a regression tree highlighting the importance of assets, 'food on credit or in lieu of work' (social capital indicator) and income sources. All continuous variables used in analyses were standardized and terminal nodes report mean FCSs for the subset with number of households (n).

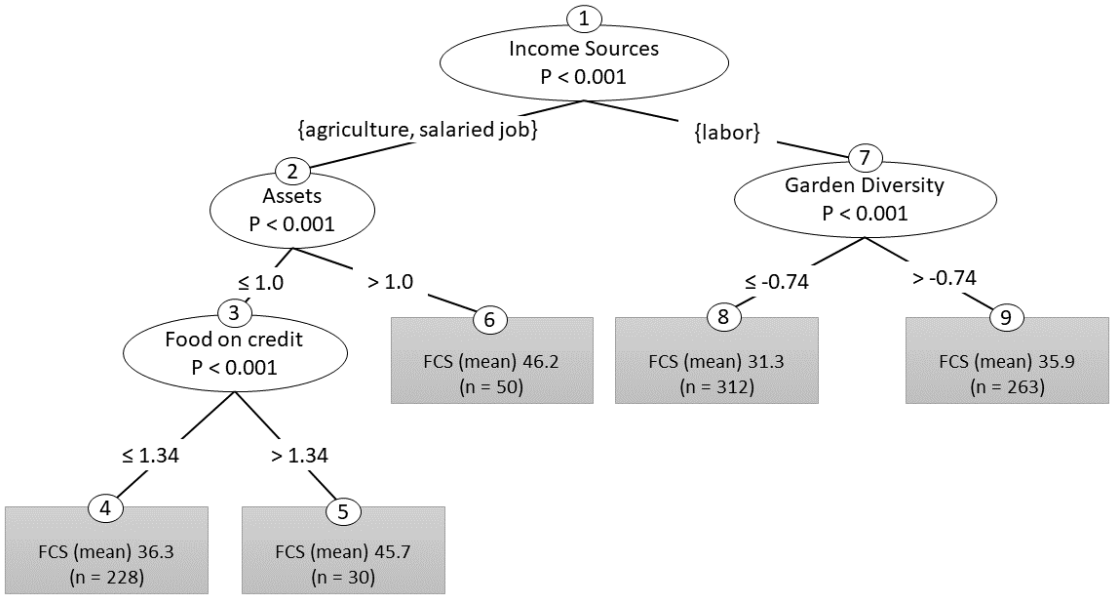


Figure 6: Winter data in regression tree analyses highlights important associations of income sources, assets, kitchen gardens, and "food on credit or in lieu of work" (social capital). All continuous variables used in analyses were standardized and terminal nodes report mean FCSs for the subset with number of households (n).

APPENDIX 3 – SUPPLEMENTARY MATERIALS FOR CHAPTER 4

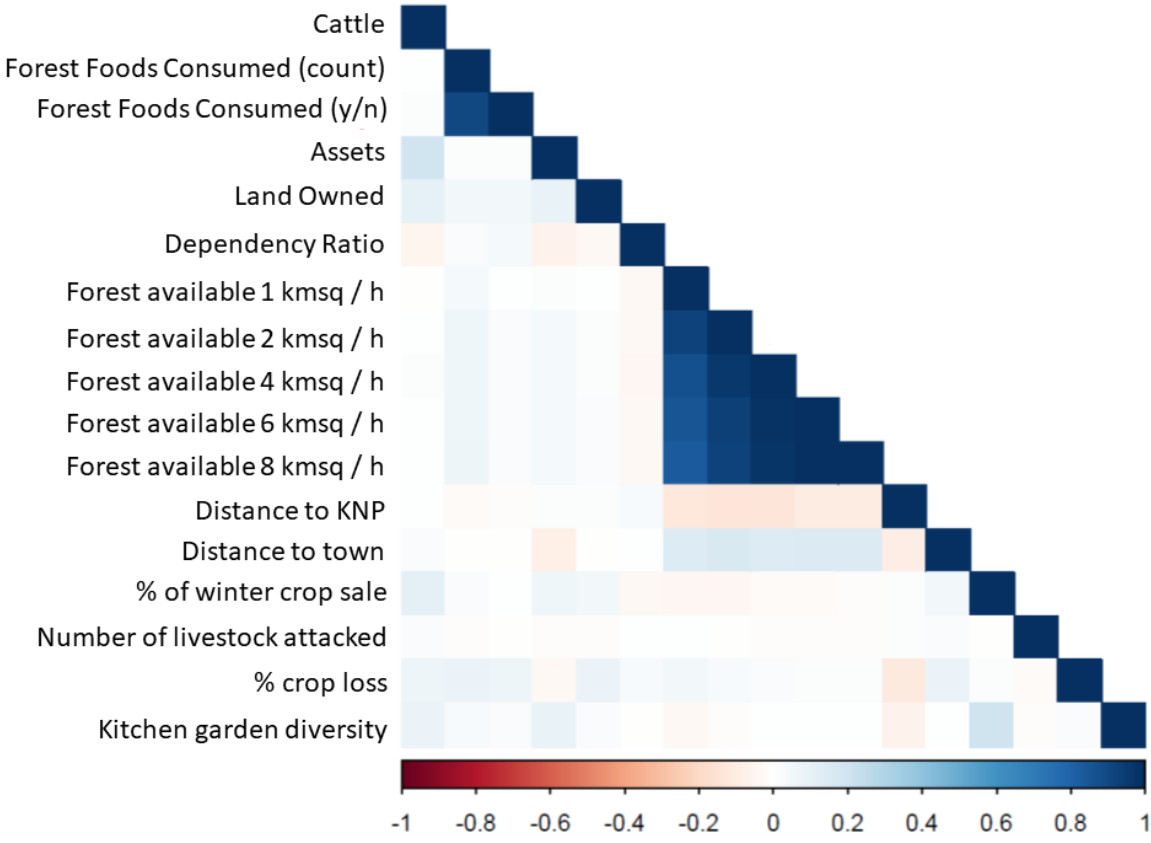


Figure 1: Models in our study use the above shown variables and additional categorical variables not depicted in the correlation plot. Forest availability measurements at various radii are correlated with each other (>0.3) and only one measurement radius was used in any one model run.

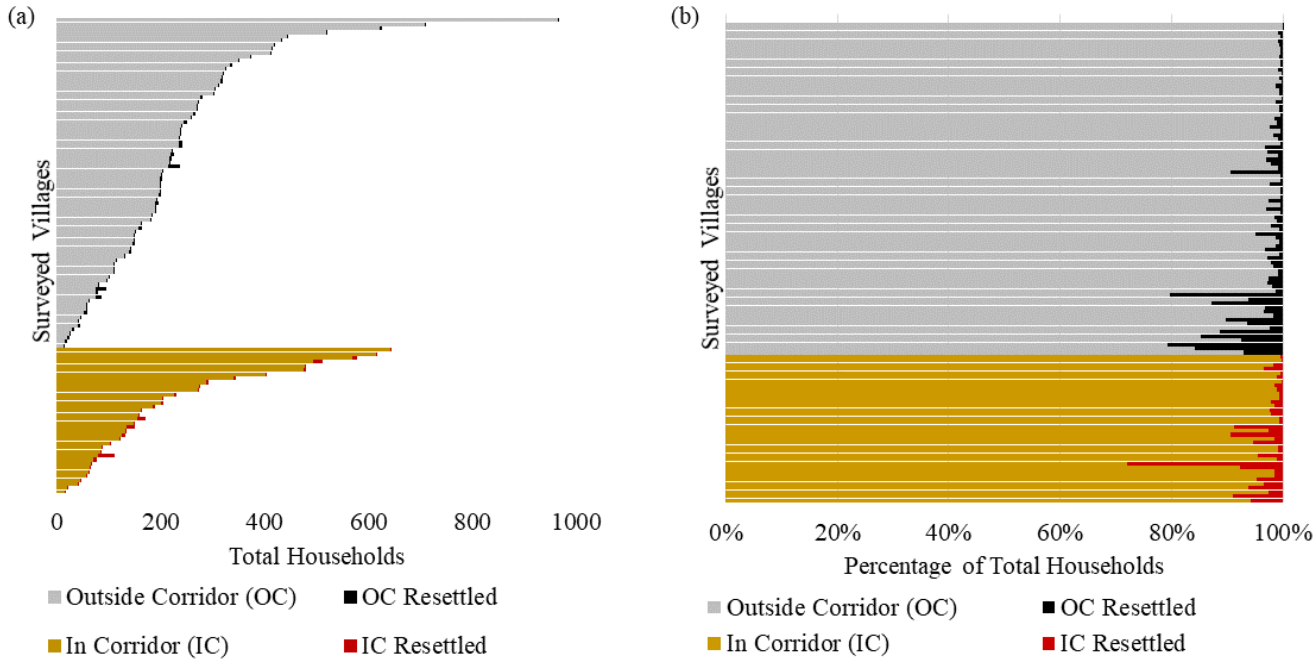


Figure 2: Influx of resettled households, joining 117 existing village populations in corridors.

Resettled households joined 117 existing villages (36 villages within and 81 villages outside wildlife corridors) in the KNP landscape as total household numbers (a) and percentage of total households (b). Resettled households are only joining a few villages in the landscape and in very smaller overall percentages of resident populations – within corridors and outside of corridors.

Table1: Corridors at different widths show the same patterns where resettled households within corridors are outnumbered manifold by resident non-resettled households.

Corridor width	Total Area (sq. kms)	% Total Area	Village Households	% Village Households	Resettled Households	% Resettled Households
20k	2171.8	13.6	16997	7.6	7	1.6
30k	2894.0	18.1	21871	9.8	47	10.4
50k	4989.2	31.2	39413	17.7	120	26.7
80k	4909.3	30.7	63724	28.6	195	43.3
100k	8387.2	52.4	81600	36.6	235	52.2
20K Width corridor (resistance values)						
Center (-10 to 6660)	951.7	5.9	8013	3.6	1	0.2
Within (6660 to 13330)	583.8	3.6	3542	1.6	2	0.4
Edge (13330 to 20000)	636.3	4.0	5442	2.4	4	0.9
30K Width corridor (resistance values)						
Center (-10 to 9993)	1173.8	7.3	8894	4.0	2	0.4
Within (9993 to 19997)	790.0	4.9	7230	3.2	19	4.2
Edge (19997 to 30000)	930.2	5.8	5747	2.6	26	5.8
50K Width corridor (resistance values)						
Center (-10 to 16660)	1837.7	11.5	13660	6.1	5	1.1
Within (16660 to 33329)	1666.3	10.4	13170	5.9	57	12.7
Edge (33329 to 50000)	1485.2	9.3	12583	5.6	58	12.9
80K Width corridor (resistance values)						

Center (-10 to 26660)	1802.4	11.3	13491	6.0	42	9.3
Within (26660 to 53329)	1618.9	10.1	10480	4.7	83	18.4
Edge (53329 - 79999)	1488.0	9.3	39753	17.8	70	15.6
100K Width corridor (resistance values)						
Center (-10 to 33326)	3268.4	20.4	24971	11.2	54	12.0
Within (33326 to 66663)	2969.3	18.6	30994	13.9	123	27.3
Edge (66663 to 99999)	2149.5	13.4	25635	11.5	58	12.9

Table 2: Mean forest use by resettled households and non-resettled neighbors in the KNP landscape: we only use data from households that reported number of cattle, tendu effort and forest foods.

Summer (s), monsoon (m)	**Non-resettled (n)**	**Resettled (n)**
Heads of Cattle		
% of surveyed households (n)	78.36 (945)	81.21 (955)
Mean	3.32	3.74
SD	2.54	2.85
Tendu days*household members (s)		
% of surveyed households (n)	12.82 (90)	5.71 (36)
Mean	38.72	41.17
SD	51.46	34.06
Forest Foods Consumed (s, m)		
% of surveyed households (n)	26.70 (322)	24.23 (285)
Mean	1.64	1.58
SD	0.66	0.68